Performance Analysis Comparison of DHT11, DHT22 and DS18B20 as Temperature Measurement

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Abstract. WMO states that temperature is an important parameter in life and defines temperature as a physical quantity that characterizes the average random motion of molecules in a physical body. The accuracy of temperature measurement on a thermometer is influenced by the selection of the right and accurate temperature sensor. There are various types of temperature sensors on the market with different principles sensor, such as electrical resistance, radiation, semiconductor, magnetic, etc. DHT11 and DHT22 sensors are the most commonly used sensors, easy to find on the market, and have the advantage of having two functions in one sensor, namely to measure air temperature and humidity. In addition, the DHT11, DHT22, DS18B20 sensors have the smallest deviation values among all existing temperature sensors. In this study, a comparison test of temperature accuracy was conducted using DHT11, DHT22, and DS18B20 sensors. Then an analysis is carried out to determine the work of the three sensors examined by laboratory calibration methods and field tests. In the Laboratory Calibration method, the DS18B20 performed the smallest uncertainty value at 0.17 °C followed by the DHT11 and DHT22 sensor at 0.18 °C of uncertainty value. It conformed with the correlation value at 0.999985, 0.999976, and 0.999098 for DS18B20, DHT22, and DHT11, respectively. Field testing is accomplished for 24 h of observation and compared with the Automatic Weather Station (AWS) data. The results of the two methods show that the three sensors have different correction values and uncertainty values with the DS18B20 sensor accuracy performance can reach 99.05%, followed by DHT22 and DHT11 at 98.15% and 97.19%, respectively.

Keywords: Temperature · Sensor · Uncertainty · Correction

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1 Introduction

World Meteorological Organization (WMO) defines temperature as the physical quantity that characterizes the mean random motion of molecules in physical body. Temperature is characterized by the behaviour of two bodies in thermal contact tend to at the same temperature [1]. Thus, temperature is a thermodynamic state of an object, and its value is determined by the net heat flow between the two objects. Temperature measurement, in its implementations, is widely used in various fields such as education, industry, agriculture, etc. In the scope of agriculture, temperature plays an essential role in controlling the plant growth [2], maintaining food quality during production, and also processing and storing in food industry [3]. Temperature monitoring also necessary in laboratories, schools, and hospital in order to maintain health and hygiene condition [2]. Therefore, it is very important to monitor changes of temperature. There are several ways to monitor temperature, one of them is by using a temperature sensor [4].

The utilization of temperature sensors were commonly implemented in simple applications such as temperature monitoring on seawater desalination devices [5], temperature monitoring on hydroponic plant controllers [6], monitoring for server rooms [7], temperature sensor control in soybean fermentation [8], which requires the selection of the right sensor that used in the proposed system.

This research is motivated by the importance of monitoring the accuracy of the temperature sensor. Temperature sensors have various types and levels of accuracy and have different sensor working principles, such as electrical resistance, radiation, semiconductors, magnets and others. Three temperature sensors consist of DHT11, DHT22 and DS18B20 will be assessed for correction value and its performance. The three temperature sensors are types of temperature sensors that are often used for simple and easy-to-implement, but these sensors have their own characteristics [9].

The DHT11, DHT22, and DS18B20 sensors have been used by some researchers related to temperature and humidity monitoring, one of them is comparing the DHT11 and LM35 sensors utilizing the Internet of Things (IoT) [10]. The results of this study indicated that the DHT11 sensor could produce a digital signal of temperature and humidity information with 97.21% accuracy which was slightly better to LM35 sensor with its 96.86% accuracy in testing the room temperature sensor. While the results of the sensor test in the server room, the DHT11 sensor had an accuracy rate of 95.26% and the LM35 sensor had an accuracy rate of 90.32%. Another related research was the assessment of the DHT22 sensor accuracy against a standard thermohygrometer [9]. This research was conducted with the five times repetition method at each variation of room temperature. This comparison produces an error value of −2.31%. The researcher concludes that the accuracy considered to be good and acceptable because it consistent with the DHT22 sensor data sheet, which was the measured temperature must have an error value of ± 5 °C.

The study of sensor accuracy had also been carried out using microcontroller systems such as Arduino Pro Mini. The research compared four sensors such as DHT11, DHT12, LM35, and DS18B20 [11]. The research tested the accuracy of four air temperature sensors by measuring the temperature with five times repetition scheme and calculate the difference or error value compared to digital thermometer which read directly. The

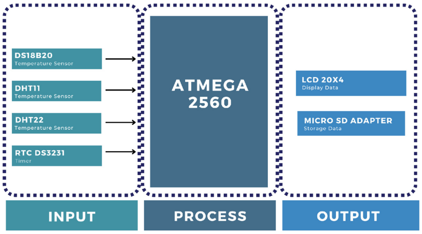

Fig. 1. The illustration of hardware system. Consist of three main steps.

measurement resulted an average error value of 4.69% for LM35 sensor, 3.12% for DHT11, 1.96% for DHT22, and 1.6% for DS18B20.

Based on the description above, this study aims to analyze the performance and accuracy of temperature measurements from the DHT11, DHT22 and DS18B20 sensors through laboratory calibration tests to obtain uncertainty values and laboratory correction values and conduct field tests to determine sensor performance, by comparing with operational termometer in Automatic Weather Station.

2 Method

The research methods conducted in this study are system design and system testing based on quantitative analysis. The design of this system consists of system block diagrams, system flow diagrams, system circuits.

2.1 Block Diagram

The block diagram is a description of how the entire system circuit works, so that the entire circuit block diagram will produce a system that can be functioned and can work as expected [12]. The illustration of block diagram was represented in Fig. 1.

There were three main steps, including input, process, and output. Input consists of temperature sensors DHT11, DHT22, DS18B20 and RTC module as a timer. The measurement and data acquisition process were carried out on the Arduino Atmega2560 microcontroller. The output of the system was stored as data which was saved in the micro sd card and displayed via the LCD display.

2.2 Circuit Design

Circuit Design in this study was carried out to create an integrated system on a Printed Circuit Board (PCB). Several electronic components in the system such as sensor modules consist of DHT11, DHT22, DS18B20, RTC modules, ATMega2560 Microcontroller, LCD Display Module, micro sd card adapter and power supply in the form of solar panels using batteries. The details illustration of the wiring system was shown in Fig. 2.

Figure 3 represented the flowchart of the designed system. The program started from the initialization of sensors and systems on the input and output ports on the microcontroller which has been set through the program [9]. After performing the initialization

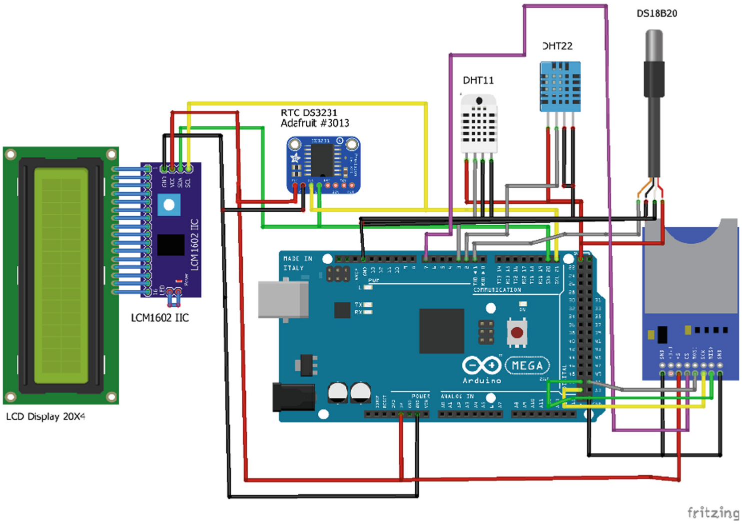

Fig. 2. The illustration of wiring system

process, the temperature sensors DHT11, DHT22, and DS18B20 then retrieved temperature data. The temperature measurement that has been taken by the sensor will be read and collected by the microcontroller and the results will be displayed on the LCD. Furthermore, the output data on the LCD is set using one-minute intervals, then the one-minute interval data will be stored to the micro-SD card.

3 Results and Discussion

3.1 Sensor Calibration Results

The calibration process for the DS18B20, DHT22 and DHT11 temperature sensors was conducted at the BBMKG Region II Laboratory. This process is carried out by comparing the measurement of the sensor which is a Unit Under Test (UUT) sensors with a standard temperature sensor in the temperature chamber. The temperature sensor and standard sensor are placed closely in the chamber. The resolution of the calibrated sensor is 0.001 °C according to the resolution of the Fluke Hart Scientific 5021A standard tool. Calibration was ruled at three set points such as 20 °C, 30 °C and 40 °C. At each set point, five measurements data were taken. The calibration data between the standard tool and the calibrated temperature sensor can be seen in Table 1.

The Table 1 shows the comparison results of standard temperature sensor and calibrated sensors. The measurement results on calibration are then included in the calculation of the combined uncertainty. In calculating the combined uncertainty, uncertainty components are included such as the uncertainty of repeated measurements, certificates of calibration of the standard thermometer, drift of the standard equipment used, operator readability, and the inhomogeneity of the media used. After calculating the uncertainty, it is concluded that the DHT11, DHT22, and DS18B20 temperature sensors have the following corrections and uncertainty.

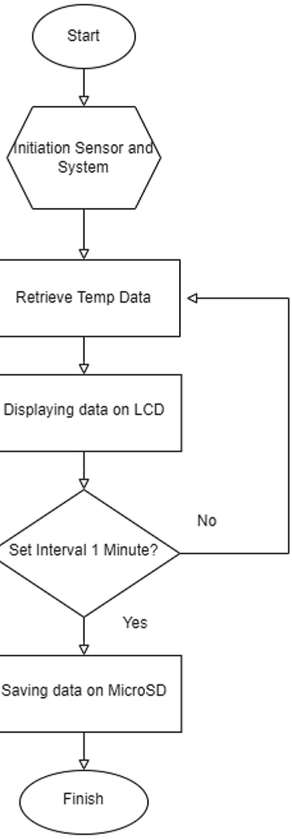

Fig. 3. The flowchart of the system.

Based on the Table 2, the lowest uncertainty value is 0.17 °C at DS18B20 sensor. Meanwhile, the DHT11 and DHT22 sensor measured the uncertainty value slightly higher at 0.18 °C. It means that the DS18B20 overall can measure the temperature better compared to DHT11 and DHT22. Mathematical model of the comparison between the temperature measurements from three sensors, DHT11, DHT22, and DS18B20 compared to the standard sensor temperature measurements is shown in Fig. 4. Calculation of the determination coefficient between sensor measurement and standard tools is needed to find out how many data points are located on the regression line, so that it can be used as an indicator of the level of accuracy of the measurement results [13].

Based on Fig. 4, the calculation of the sensor determination coefficient shows that the DS18B20 sensor has a better correlation value of 0.999985, followed by the DHT22 sensor of 0.999976, and DHT11 of 0.999098.

3.2 Field Testing

After the calibration process was carried out to determine corrections and uncertainty, the sensors were tested at the surface-based meteorological station field. Field testing

Table 1. The calibration results with three set points

SETPOINT	SENSOR STD	DHT11		DHT22		DS18B20	
		Value	Correction	Value	Correction	Value	Correction
20 °C	20.033	19.8	0.23	19.8	0.23	19.4	0.66
	20.059	19.8	0.26	19.7	0.36	19.3	0.75
	19.977	19.8	0.18	19.5	0.48	19.3	0.67
	19.989	19.8	0.19	19.6	0.39	19.4	0.62
	20.019	19.8	0.22	19.7	0.32	19.4	0.58
Mean	**20.015**	**19.8**	**0.22**	**19.66**	**0.36**	**19.4**	**0.66**
30 °C	29.999	29.8	0.20	29.5	0.50	29.3	0.69
	30.003	29.8	0.20	29.5	0.50	29.3	0.69
	30.013	29.8	0.21	29.5	0.51	29.3	0.70
	30.091	30.2	−0.11	29.7	0.39	29.5	0.59
	30.104	30.2	−0.10	29.7	0.40	29.5	0.60
Mean	**30.042**	**29.96**	**0.08**	**29.58**	**0.46**	**29.4**	**0.66**
40 °C	40.053	41.6	−1.55	39.4	0.65	39.4	0.67
	40.055	41.6	−1.55	39.4	0.66	39.4	0.67
	40.057	41.6	−1.54	39.4	0.66	39.4	0.68
	40.060	41.6	−1.54	39.4	0.66	39.4	0.68
	40.063	41.6	−1.54	39.4	0.66	39.4	0.68
Mean	**40.058**	**41.6**	**−1.54**	**39.4**	**0.66**	**39.4**	**0.68**

Table 2. The three sensors correction and uncertainty. All values are in degree of celcius (°C).

Standardized Temperature	DHT11			DHT22			DS18B20		
	Meas.	Corr.	U_{95}	Meas.	Corr.	U_{95}	Meas.	Corr.	U_{95}
20.015	19.8	0.22	0.18	19.7	0.36	0.26	19.4	0.66	0.18
30.042	30.0	0.08	0.33	29.6	0.46	0.22	29.4	0.66	0.21
40.058	41.6	−1.54	0.18	39.4	0.66	0.18	39.4	0.68	0.17

Note: Meas. = Measurement
Corr. = Correction
U_{95} = Uncertainty

of the sensors was aimed to determine the performance of the sensor in conducting temperature data acquisition for about 24 h. Field testing is carried out by comparing the temperature data from the system with the temperature of the operational equipment, named Automatic Weather Station (AWS).

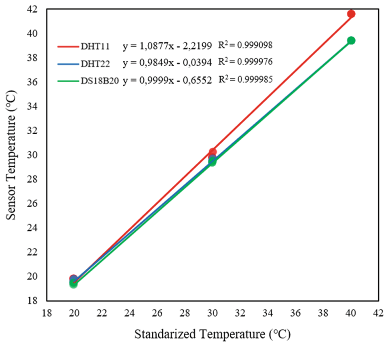

Fig. 4. Determination coefficient between the tested sensors and standardized sensor

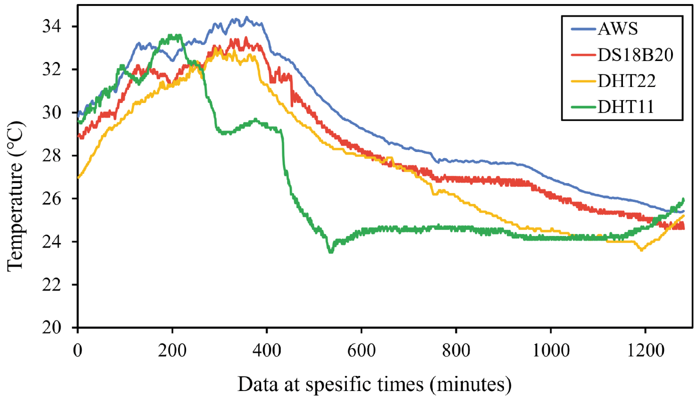

Fig. 5. The time series of temperature data from the sensors

Figure 5 is a visualization of the sensor observation data on the Automatic Weather Station (AWS) compared with three tested sensors which take some observation data from August 20, 2022 to August 21, 2022. Based on the calculation, the average correction obtained from the DS18B20 sensor is 0.95 °C, DHT22 is 1.85 °C and DHT11 is 2.81 °C.

In terms of functionality, the designed system has been able to generate temperature value data for statistical processing. The test from Laboratory of Calibration and Field Testing have been carried out quite well. The Laboratory tests which experience at 20 °C, 30 °C and 40 °C setpoints, resulted that the DS18B20 sensor has the smallest uncertainty value at each setpoint. This value indicates that the DS18B20 sensor quality is better than the other two sensors. To validate the quality of these sensors, field testing is conducted. The field test was carried out for 24 h which compared to the temperature sensor on the operational AWS. The results of the field test showed that the average correction value of 0.95 °C, 1.85 °C, and 2.81 °C for DS18B20, DHT22, and DHT11, respectively. Meanwhile, the percentage accuracy of the DS18B20 sensor is 99.05%, followed by DHT22 sensor accuracy at 98.15% and DHT11 at 97.19%.

4 Conclusion

A comparison test of temperature sensors accuracy was conducted on three sensors such as DHT11, DHT22, and DS18B20. There are two methods used to determine the performance of the sensors, laboratory calibration and field test. In the Laboratory Calibration Method, the sensors were put into the chamber calibrator and tested with three setpoints, they are 20 °C, 30 °C, and 40 °C, and obtained the correction value of each setpoint and uncertainty value. The results depict that DS18B20 performed with smallest uncertainty value at 0.17 °C followed by the DHT11 and DHT22 sensor at 0.18 °C of uncertainty value for both sensors. This value related with the correlation value at 0.999985, 0.999976, and 0.999098 for DS18B20, DHT22, and DHT11, respectively. Meanwhile, the field testing is carried out for 24 h of observation and compared with the Automatic Weather Station (AWS) data. The results of the two methods show that the three sensors have different correction values and uncertainty values with the DS18B20 sensor has the highest accuracy which performed 99.05% in its accuracy, followed by DHT22 and DHT11 at 98.15% and 97.19%, respectively.

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