DS18B20 Sensor Calibration Compared with Fluke Hart Scientific Standard Sensor

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Abstract---The DS18B20 sensor calibration has been conducted using a fluke hart with a temperature chamber at the center for meteorology, climatology, and geophysics region III Denpasar. The calibration process is done by stabilizing the temperature in the chamber, then the temperature on the DS18B20 sensor and the standard thermometer in the chamber are read and compared. The setpoints used were 10 ºC, 20 ºC, 30 ºC and 40 ºC each set point was read four times. The results of the calculation of the standard deviation at each setpoint are $\pm$ 0,39 ºC, $\pm$ 0,12 ºC, $\pm$ 0,00 ºC, $\pm$ 0,00 ºC and the results of the uncertainty for each setpoint are 0,65 ºC, $\pm$ 0,20 ºC, $\pm$ 0,18 ºC, $\pm$ 0,18 ºC. The results of the DS18B20 sensor calibration using a fluke hart with a temperature chamber obtained the highest standard deviation value of $\pm$0,39 ºC and the highest uncertainty value was 0,65 ºC. This value indicates that the DS18B20 sensor calibrated with a standard tool at the 10 ºC set point has not met the standard value applied by WMO, which is $\pm$0.3 ºC.
Keywords---calibration, DS18B20 sensor, fluke hart, temperature chamber.

Introduction

Measurement is a series of activities that aim to determine the value of a quantity in numerical form (quantitative). The measuring instrument used for measurement is of course an accurate measuring tool in measurement so that the data obtained is following the conditions in the field (Dhofir, 2014; Galiancoli, 2001; Lewis et al., 2016). However, if a measuring instrument is used for a long time or repeatedly used without stopping, it can affect the accuracy of the measuring instrument. This happens due to the influence of various things, such as the influence of the environment, the influence of the old components of the tool, and others. The inaccuracy of the measuring instrument is calculated employing calibration. Calibration is an activity to find out the conventional truth of the designation value of a measuring instrument (Chan, 2011).

The thermometer is a temperature measuring instrument, which is often used in laboratories, factories, and others. The thermometer that is widely used by the community is the mercury/analog thermometer. Apart from being relatively cheaper than digital thermometers, mercury thermometers are also easy to use. Good or bad the results of thermometer measurements greatly affect many things, such as the results of measuring a person's body temperature (Bamodu et al., 2017; Kapen et al., 2019; Simbeye et al., 2014).

Thermometers that are used too often or have been used for a long time must be calibrated. To calibrate a thermometer, tools can be used, namely the chamber temperature and bath temperature. The temperature chamber is

1

more often used to calibrate the thermometer when compared to the bath temperature (Frei et al., 2020; Vega et al., 2020; Bamodu et al., 2018). The use of a temperature bath is more complicated when compared to a temperature chamber because the use of a temperature bath must be filled with liquid (glycol) in it to perform the calibration and can only calibrate a glass thermometer. In this study, a temperature measuring instrument will be designed to be calibrated with a standard tool at the BMKG (2013), namely a fluke hart with a temperature chamber. The tool used to calibrate the temperature is the DS18B20 sensor.

Method

Before performing the calibration, the sensor tools are designed to be used in the calibration process. The design of the device is divided into two parts, namely the design of the hardware and the design of the software. In designing the tool, the sensor used is the DS18B20 sensor based on Arduino Uno. DS18B20 functions are as a temperature reader. The DS18B20 is connected to the Arduino Uno using a jumper cable. There are two wiring methods for DS18B20 to Arduino Uno which are I2C and SPI. The wiring method used is I2C, using SDA, SCL, GND, and VCC pins. After the design is complete, then sketch an Arduino IDE application. The sketch-making process will be explained in the software design section. Designing hardware using the *proteus* application can be seen in Figure 1.
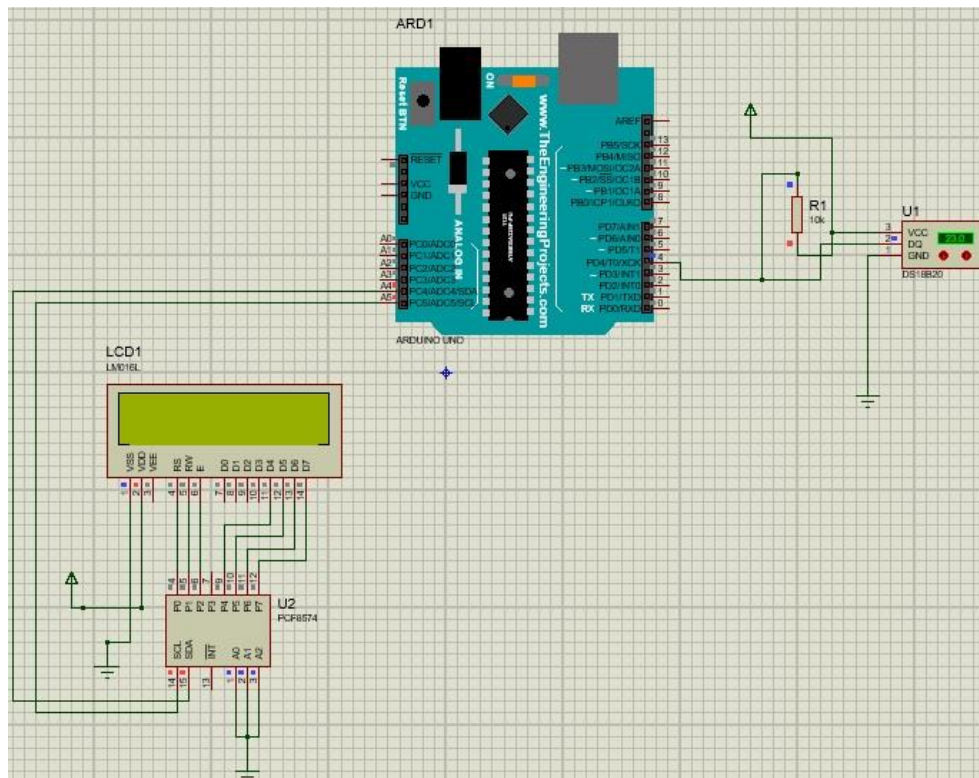

Figure 1. Schematic of hardware design with proteus

The block diagram of the DS18B20 temperature sensor hardware design is shown in Figure 2.

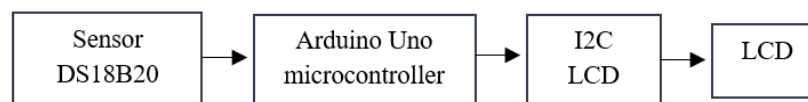Figure 2. Block diagram of how the tool to measure temperature works

The signal response flow shown in Figure 2 starts with the DS18B20 sensor which converts the input signal in the form of a temperature into an analog signal in the form of a voltage. One wire bus is on the DS18B20 sensor so that the ATMEGA328P microcontroller on the Arduino Uno can distinguish the data sent from the DS18B20 sensor. The

ATMEGA328P microcontroller which already contains an *Analog to Digital Converter (ADC)* converts analog signals into digital data. The digital data obtained is then processed by the ATMEGA328P microcontroller and forwarded to the I2C LCD module (Nagy et al., 2014; Bohórquez et al., 2009). The I2C LCD module sends data to the LCD which will display temperature data. The temperature data that appears on the LCD shows the measured temperature results. This software design explains the flow of programming following the rules of the programming language used is C language. For a microcontroller (Arduino), an application called the Arduino IDE is needed. The flow of making a sketch can be seen in the flow chart in Figure 3.
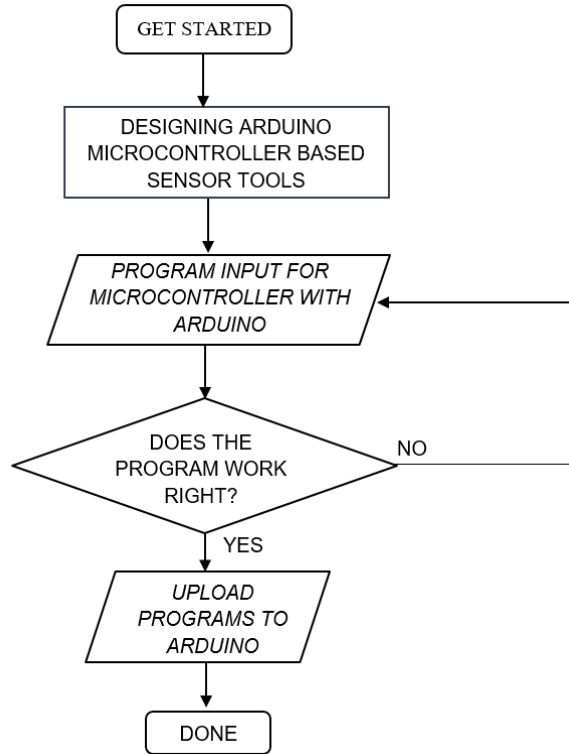
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┌──────────────┐
│ GET STARTED  │
└──────────────┘
        │
        ▼
┌──────────────────────┐
│  DESIGNING ARDUINO   │
│ MICROCONTROLLER BASED│
│    SENSOR TOOLS      │
└──────────────────────┘
        │
        ▼
┌──────────────────────┐
│  PROGRAM INPUT FOR   │
│ MICROCONTROLLER WITH │◄───────┐
│      ARDUINO         │        │
└──────────────────────┘        │
        │                       │
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     ╱────────╲                 │
    ╱ DOES THE ╲    NO          │
   ╱ PROGRAM WORK ╲─────────────┘
    ╲   RIGHT?   ╱
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        │ YES
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┌──────────────────────┐
│  UPLOAD PROGRAMS TO  │
│      ARDUINO         │
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┌──────────┐
│   DONE   │
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Figure 3. Flowchart of software design

Results

Comparison Results

Comparison of the results of the DS18B20 sensor calibration with the fluke hart scientific sensor through the media temperature chamber on a scale of 10^oC, 20^oC, 30^oC, dan 40^oC at the central laboratory for meteorology and climatology and geophysics region III Denpasar. The results of the DS18B20 sensor calibration with the Fluke Hart scientific sensor through the media temperature chamber are shown in Table 1.

Table 1
The results of the DS18B20 sensor calibration with the fluke hart scientific sensor through the media temperature chamber

Set point	Standard tools			Calibrated tool (℃)	Correction
	Temperature reading (℃)	Correction (℃)	Temperature (℃)		
	10,009	-0,06	9,953	9,29	0,66
10^oC	10,045	-0,06	9,989	9,29	0,70
	10,600	-0,06	10,542	9,29	1,25

	10,780	-0,06	10,721	9,29	1,43
	Average		10,313	9,29	1,01
	20,084	-0,10	20,074	19,54	0,53
	20,090	-0,10	20,080	19,54	0,54
20^oC	20,093	-0,10	20,083	19,54	0,54
	20,108	-0,10	20,098	19,54	0,77
	Average		20,084	19,54	0,60
	30,003	-0,002	30,001	29,54	0,46
	30,004	-0,002	30,002	29,54	0,46
30^oC	30,005	-0,002	30,003	29,54	0,46
	30,012	-0,002	30,010	29,54	0,47
	Average		30,004	29,54	0,46
	40,004	0.002	40,006	39,66	0,35
	40,007	0.002	40,009	39,66	0,35
40^oC	40,012	0.002	40,014	39,66	0,35
	40,015	0.002	40,017	39,66	0,36
	Average		40,012	39,66	0,35

Discussion

Before the sensor is levelled to accuracy, it must first be calibrated. Location of calibration for temperature sensors at the laboratory of the center for meteorology, climatology, and geophysics region III Denpasar. The purpose of calibration is to determine the level of closeness to the results of measuring instruments designed with standard tools. The temperature calibration process is carried out at several set points as sample points. The selected setpoints are 10 ℃, 20 ℃, 30 ℃, and 40 ℃. Calibration is done by using a comparison method where the sensor to be tested is placed side by side with a standard sensor in a place called a chamber. After that, the temperature value is read repeatedly at least four times at each setpoint. The tolerance value set by the *World Meteorological Organization (WMO)* is ±0,3 ℃. Figure 4 shows that the DS18B20 temperature sensor calibration process is running.

Figure 4. DS18B20 sensor calibration process

The data logger is placed side by side with a standard temperature reading display to make it easier to record the readings on each sensor. The calibration process is carried out by recording each temperature on the standard tool and design tool so that from the calibration results, the standard deviation and uncertainty values are obtained. The standard deviation can be calculated by the following equation:

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

Annotation:

  SD = standard deviation
  x_i = sample value
  $\bar{x}$ = sample mean value
  n = amount of data

At the first set point, which is 10 °C, the first temperature reading on the standard sensor is 10,009 °C, at this temperature the standard sensor has a correction of -0,56 °C. So that the temperature in the chamber is 9,953 °C and the reading. The temperature on the calibrated DS18B20 sensor is 9,29 °C. So that the correction value on the DS18B20 sensor can be calculated from the reduction in the temperature value on the standard tool with the temperature value on the DS18B20 sensor and a correction value is obtained of 0,66 °C. Then do the same for the second, third, and fourth readings. The results of this correction calculation can then be used to calculate the standard deviation, as shown in Table 2.

Table 2. Calculation of the standard deviation at the 10 °C set point

No	x_i (correction)	$\bar{x}$	$(x_i - \bar{x})$	$(x_i - \bar{x})^2$
1	0,66	1,01	-0,35	0,1225
2	0,70	1,01	-0,31	0,0961
3	1,25	1,01	0,24	0,0576
4	1,43	1,01	0,42	0,1764

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

$$SD = \sqrt{\frac{0,1225 + 0,0961 + 0,0576 + 0,1764}{4(4-1)}}$$

$$SD = 0,39$$

The result of the standard deviation of the DS18B20 sensor at the set point of 10 °C at the chamber temperature is 0,39. To find the standard deviation of the second, third, and fourth set points. It is done as the steps in the first set point. The results of the standard deviation calculation are shown in Table 3.

Table 3
The results of the calculation of standard deviation on the second, third, and fourth set points

Set Point (°C)	Standard deviation (±)
10	0,39
20	0,12
30	0,00
40	0,00

The four standard deviation results obtained from the DS18B20 sensor calibration with standard tools at the laboratory of the center for meteorology and geophysics region III Denpasar were not more than 0.3. The value of uncertainty on the DS18B20 sensor against the standard maximum uncertainty value according to the *World*

Meteorological Organization (WMO) is $\pm 0,3\,^oC$, if it exceeds this value it can be said that the measurement results from the thermometer are very far from these standards or thermometers are not suitable for meteorological operations. So that from the results of the DS18B20 sensor uncertainty on the setpoint 10 ^{o}C does not meet the standard WMO uncertainty value and the setpoint 20 ^{o}C, 30 ^{o}C, 40 ^{o}C meets the standard WMO uncertainty value, which is $\pm 0,3$ ^{o}C. The results of the DS18B20 sensor uncertainty value are shown in Table 4.

Table 4
Results of the DS18B20 sensor uncertainty value

Setpoint	Standard Temperature	Calibrated Tool	Correction	U95 ±
°C	°C	°C	°C	°C
10	10,31	9,29	1,01	0,65
20	20,08	20,00	0.60	0,20
30	30,00	29,54	0.46	0,18
40	40,01	39,66	0,35	0,18

Table 4 shows the DS18B20 sensor which is calibrated at each reading then the highest value and uncertainty value is taken from the sensor where the uncertainty value must meet the specified conditions, namely $\pm 0,3$ ^{o}C, the highest value of uncertainty obtained on the DS18B20 sensor is 0.65, This means that the 10 ^{o}C setpoint does not meet the intended requirements and is not feasible to operate because it is still far from the standard value of the *World Meteorological Organization (WMO),* but at the 20 ^{o}C, 30 ^{o}C, 40 ^{o}C set point it is feasible to be operationalized in the field of meteorology.

Conclusion

Based on the discussion, it can be concluded, firstly, The DS18B20 sensor calibration process with a fluke hart by stabilizing the temperature in the chamber and by reading the temperature on a standard thermometer through the chamber temperature. Secondly, The results of the DS18B20 sensor calibration with a fluke hart through the media temperature chamber obtained the highest standard deviation value of 0,39 ^{o}C. Thirdly, The DS18B20 sensor meets the *World Meteorological Organization (WMO)* standard, which is $\pm 0,3$ ^{o}C.

References
Bamodu, O., Osebor, F., Xia, L., Cheshmehzangi, A., & Tang, L. (2018). Indoor environment monitoring based on humidity conditions using a low-cost sensor network. *Energy Procedia*, *145*, 464-471. https://doi.org/10.1016/j.egypro.2018.04.093
Bamodu, O., Xia, L., & Tang, L. (2017). An indoor environment monitoring system using low-cost sensor network. *Energy Procedia*, *141*, 660-666. https://doi.org/10.1016/j.egypro.2017.11.089
BMKG (2013). *Metode Kalibrasi Meteorologi*, Laboratorium Kalibrasi BMKG, Jakarta.
Bohórquez, M. A. M., Gomez, J. M. E., & Marquez, J. M. A. (2009). A new and inexpensive temperature-measuring system: Application to photovoltaic solar facilities. *Solar Energy*, *83*(6), 883-890. https://doi.org/10.1016/j.solener.2008.12.007
Chan, Y. (2011). *Sistem Pengukuran Teknik,* Universitas Darma Persada, Jakarta.
Dhofir, A. (2014). *Pengukuran Suhu Termometer,* Universitas Muhammadiyah Malang, Jawa Timur.
Frei, M., Deb, C., Stadler, R., Nagy, Z., & Schlueter, A. (2020). Wireless sensor network for estimating building performance. *Automation in Construction*, *111*, 103043. https://doi.org/10.1016/j.autcon.2019.103043
Galiancoli, D. (2001). *Fisika Edisi Ke-5 Jilid 1,* Erlangga, Jakarta.
Kapen, P. T., Mohamadou, Y., Momo, F., Jauspin, D. K., Kanmagne, N., & Jordan, D. D. (2019). Development of a neonatal incubator with phototherapy, biometric fingerprint reader, remote monitoring, and heart rate control adapted for developing countries hospitals. *Journal of Neonatal Nursing*, *25*(6), 298-303. https://doi.org/10.1016/j.jnn.2019.07.011
Lewis, A. J., Campbell, M., & Stavroulakis, P. (2016). Performance evaluation of a cheap, open source, digital environmental monitor based on the Raspberry Pi. *Measurement*, *87*, 228-235. https://doi.org/10.1016/j.measurement.2016.03.023

Nagy, Z., Rossi, D., Hersberger, C., Irigoyen, S. D., Miller, C., & Schlueter, A. (2014). Balancing envelope and heating system parameters for zero emissions retrofit using building sensor data. *Applied energy*, *131*, 56-66. https://doi.org/10.1016/j.apenergy.2014.06.024

Simbeye, D. S., Zhao, J., & Yang, S. (2014). Design and deployment of wireless sensor networks for aquaculture monitoring and control based on virtual instruments. *Computers and Electronics in Agriculture*, *102*, 31-42. https://doi.org/10.1016/j.compag.2014.01.004

Vega, F. A. O., Ríos, A. P. M., Saraz, J. A. O., Quiroz, L. G. V., & Damasceno, F. A. (2020). Assessment of black globe thermometers employing various sensors and alternative materials. *Agricultural and Forest Meteorology*, *284*, 107891. https://doi.org/10.1016/j.agrformet.2019.107891