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# Development of an Automated Temperature Calibration Monitoring System Using Internet of Things for the Regional Meteorology, Climatology, and Geophysics Agency (Bmkg) in Medan

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**Abstract**

The Regional Meteorology, Climatology, and Geophysics Agency (BMKG) plays a crucial role in providing accurate and reliable services related to meteorology, climatology, and geophysics. Temperature observation is one of the important tasks carried out by the BMKG as it is essential for weather and climate forecasting, as well as for predicting natural disasters. To ensure the accuracy of the data, the thermometers used for temperature observation must be in good working condition and calibrated regularly. According to the Republic of Indonesia Law No. 31, Article 48, Year 2009 on Meteorology, Climatology, and Geophysics (MKG), all observation equipment must be in good working condition and calibrated regularly. Calibration is a crucial step in ensuring the accuracy and operational fitness of the observation equipment. The International Organization for Standardization (ISO) / International Electrotechnical Commission (IEC) 17025:2017 also emphasizes the importance of ensuring the quality and accuracy of all measurement instruments. The Calibration Laboratory at the BMKG Regional Office I in Medan is accredited with ISO/IEC 17025:2017 by the National Accreditation Committee (KAN). However, the calibration process can be time-consuming and requires constant monitoring to achieve stable data. During temperature and humidity calibration, the calibration laboratory's environment must be conditioned to maintain the performance of sensitive instruments that are susceptible to environmental changes. This study aims to design an automated temperature calibration monitoring system using the Internet of Things (IoT) to improve the efficiency of the calibration process and achieve maximum calibration results at the BMKG Regional Office I in Medan. The system will enable the calibration personnel to monitor the calibration process remotely and receive real-time data, allowing for more effective analysis and decision-making.

**Keywords**: Temperature observation, calibration, internet of things, monitoring system.

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## INTRODUCTION

The Meteorology, Climatology, and Geophysics Agency (BMKG) is an institution responsible for providing fast, accurate, extensive, and easily understandable services in the field of meteorology, climatology, and geophysics. Temperature observation is one of the important tasks carried out by the BMKG. Temperature observation data is crucial for weather and climate forecasting, as well as estimating potential natural disasters.

Temperature observations are conducted using thermometers, both analog and digital. Every equipment used for observation must be operational and calibrated to ensure data accuracy. According to the Republic of Indonesia Law No. 31, Article 48, Year 2009 on Meteorology, Climatology, and Geophysics (MKG), all observation equipment operated at the observation stations must be operational, and periodic calibration is necessary to ensure their operability. Calibration activities are conducted by competent institutions in accordance with the regulations.

The International Organization for Standardization (ISO)/International Electrotechnical Commission (IEC) 17025:2017 states that all measurement instruments used in production must ensure the accuracy of their measurements. Calibration is the primary step to ensure accuracy and operational fitness of the observation equipment. Calibration is the process of verifying the accuracy of a measuring instrument (unit under test) with standard equipment (Muksan, 2022). The BMKG Regional Center I in Medan has a calibration laboratory accredited with ISO/IEC 17025:2017 by the National Accreditation Committee (KAN).

The calibration process requires a significant amount of time to achieve stable data. During the calibration process, personnel need to continuously monitor the process. In temperature and humidity calibration, the calibration laboratory for temperature and humidity monitoring needs to condition its environment to maintain the performance of instruments that are sensitive to environmental changes (Syafrina, 2017). This requires the calibration room to be in a stable condition and should not be opened or closed frequently.

In a study conducted by Joseph (2012) on the design of a weather parameter monitoring device using the Internet of Things, the study focused on monitoring systems for temperature, humidity, and PM 2.5 using digital sensors and Raspberry Pi. The results of the study showed that the device functioned well and enhanced analysis effectiveness as it could be accessed through a website with an intranet. Furthermore, a study by Nuha (2021) designed a device to monitor temperature in a climatic chamber using Arduino. This study employed temperature sensors, and the acquired data was stored in Excel format.

Based on the aforementioned background and previous research, this study aims to design an automated temperature calibration monitoring system using the Internet of Things to improve the effectiveness of calibration personnel and achieve optimal calibration results at the BMKG Regional Center I in Medan.

## METHOD

The design of this system aims to provide convenience in the creation of the device, resulting in the formation of a well-functioning system that meets expectations while considering the characteristics of the components used.

The concept of system design is a part that discusses in detail the overview of the entire system so that the system can be formed and function properly. This system design consists of a DHT22 temperature sensor, Arduino Uno, buzzer, and a camera connected to an Android or PC. The calibration process is as follows:

1. The operator places the device to be calibrated into the chamber.
2. The operator turns on the chamber and sets the desired temperature.
3. The operator waits for the temperature to stabilize, then records the temperature displayed on the tested device and the standard device four times.
4. The calibration process is completed.

The above calibration process is carried out according to standard procedures. However, there are some drawbacks to this process, which are as follows:

1. The effectiveness of the operator's work decreases because the process of waiting for the temperature to stabilize takes a long time, and the operator needs to continuously observe it. If this time is used for other tasks, it would be more productive.
2. The temperature of the calibration room will be affected when the operator opens the door for entering and exiting the calibration room, whereas according to the calibration room rules, the temperature should remain stable at 24 degrees Celsius.

The solution to the above problems is to create a system that can automatically notify when the temperature has stabilized, and the observer can monitor it from anywhere. This would increase the effectiveness of the observer's work.

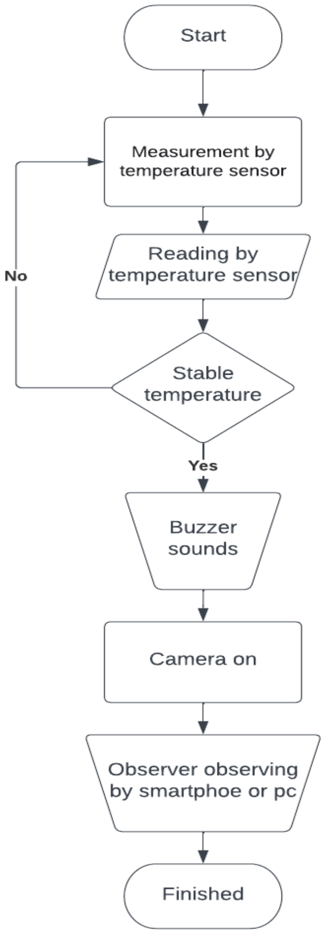


**Figure 1.** Flowchart diagram

Figure 1 displays the flowchart diagram of the system to be created. The input to the system is the temperature sensor, which is then forwarded to the data logger. When the data becomes stable, an alarm will sound, and notifications will be received. The data can be viewed from the camera from anywhere.

The schematic design of a system is a simulation of the design that serves as a reference when creating the actual system. The circuit schematic of the monitoring system design is shown in Figure 2.

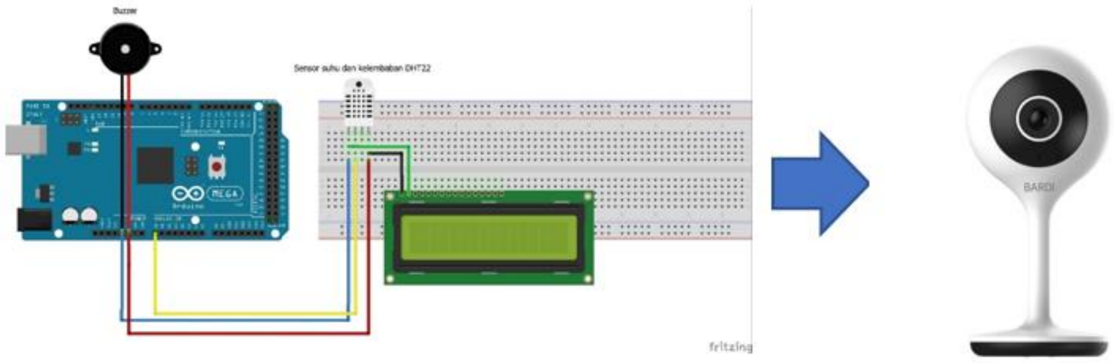

**Figure 2.** System network schematic

The system consists of a DHT22 temperature and humidity sensor and a Buzzer. The sensor's output will be forwarded to the Arduino Mega 2560 for data processing. The processed data will then be displayed on a 16x2 LCD screen. The Buzzer will sound when the temperature reaches stability during the calibration process.

When the Buzzer sounds, the camera will detect it and send a notification to a smartphone. The operator can open their smartphone and observe the system from anywhere through the live camera feed.

## RESULTS AND DISCUSSION

The testing is conducted by examining the device within a specific temperature range. In this case, a set point of 30 degrees Celsius is used. Before the testing, the sensor used is calibrated to ensure accurate and traceable readings.

The temperature sensor will be calibrated prior to testing to ensure the accuracy of the data, approaching the actual values. The calibration will be performed at set points of 20, 30, and 40 degrees Celsius.

**Table 1.** Sensor DHT22 calibration result

| Set Point | Standard (°C) Reading | Standard (°C) Correction | Standard (°C) Corrected | UUT (°C) Reading | UUT (°C) Correction | Average correction | Standard Devition |
|---|---|---|---|---|---|---|---|
| 20 | 20,0920 | 0,008 | 20,100 | 20 | 0,1 | 0,1 | 0,0 |
| | 20,0922 | 0,008 | 20,100 | 20 | 0,1 | | |
| | 20,0926 | 0,008 | 20,101 | 20 | 0,1 | | |
| | 20,0927 | 0,008 | 20,101 | 20 | 0,1 | | |
| 30 | 29,9929 | 0.016 | 30,009 | 30 | 0,0 | 0,0 | 0,0 |
| | 29,9949 | 0.016 | 30,011 | 30 | 0,0 | | |
| | 29,9961 | 0.016 | 30,012 | 30 | 0,0 | | |
| | 29,9975 | 0.016 | 30,130 | 30 | 0,0 | | |
| 40 | 40,0306 | 0,022 | 40,053 | 40 | 0,1 | 0,0 | 0,0 |
| | 40,0300 | 0,022 | 40,052 | 40 | 0,1 | | |
| | 40,0296 | 0,022 | 40,052 | 40 | 0,1 | | |
| | 40,0294 | 0,022 | 40,051 | 40 | 0,1 | | |
| **Average correction** | | | | | | 0,033 | |

The sensor's condition during calibration is placed inside a temperature chamber. The calibration process is carried out by setting the chamber to alternating set points of 20°C, 30°C, and 40°C, and recording the temperature values from the sensor and the standard device for four readings to determine the correction and deviation values.

Table 1 shows that the resulting data is excellent. This can be observed from the average correction value of 0.033 and a standard deviation of 0, indicating high accuracy and precision.

*System testing process*

The system's data logger is placed on top of the temperature chamber, while the temperature sensor is placed inside the chamber. The temperature sensor is connected to the data logger using a LAN cable, establishing a connection between them. This setup allows the data logger to capture and record temperature readings from the sensor within the temperature chamber.

**Figure 3.** Overall view of the system after installation and assembly

Before conducting the testing, the camera is positioned in front of the temperature chamber to observe the values displayed on the standard display and the calibrated device. This allows for monitoring and comparison of the readings from both sources.

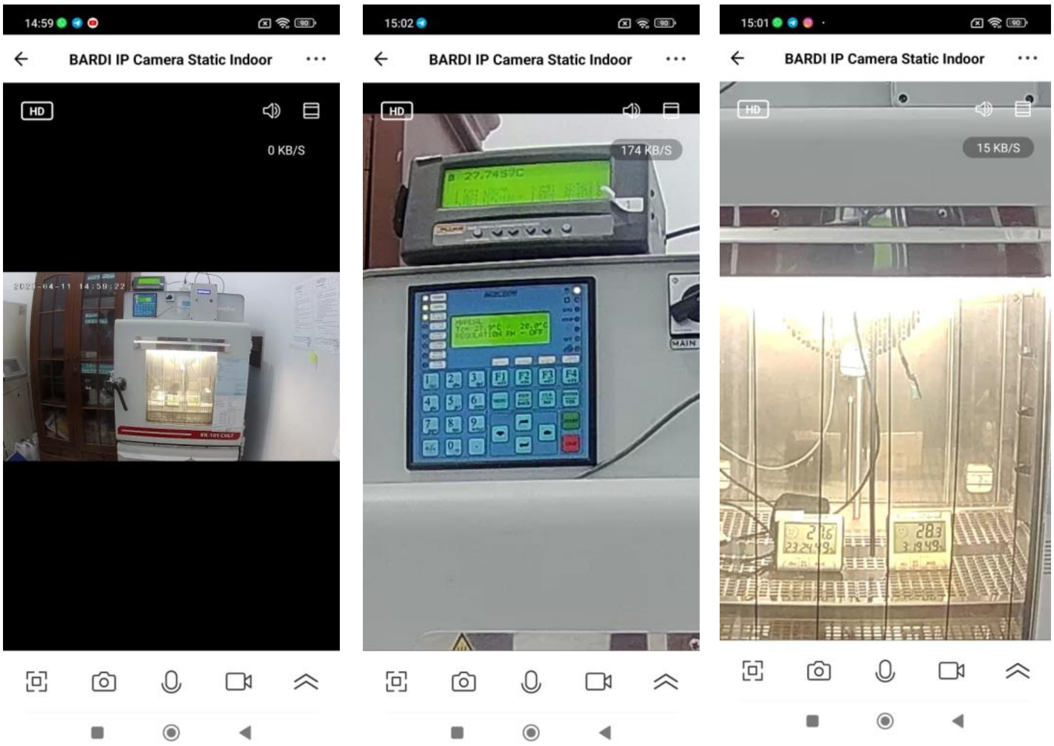


**Figure 4.** Camera view when opened from a smartphone

Figure 4 illustrates the display of the Bird's-eye camera captured from a smartphone, which is used to monitor temperature values. The image can be zoomed in and zoomed out, allowing users to enlarge or reduce the image as needed. With this feature, users can clearly observe the displayed temperature values on the device's screen or the standard display located inside the temperature chamber.

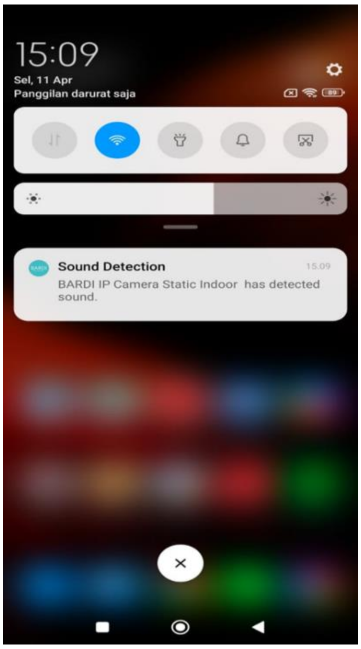


**Figure 5.** Notification from camera on smartphone

Figure 5 displays the notification that appears on a smartphone after the alarm sounds. The alarm activates when the temperature from the temperature sensor reaches a stable condition. If the notification is clicked, the camera view will open, allowing the user to directly access the live camera feed.

*System Analysis*

After the final design, an analysis of the data generated by the system is conducted. The testing is performed by collecting data for one hour, starting with a set point of 30 degrees Celsius. The data collection begins with the ambient room temperature and is carried out in a closed room where no personnel are allowed to enter during the data collection process.

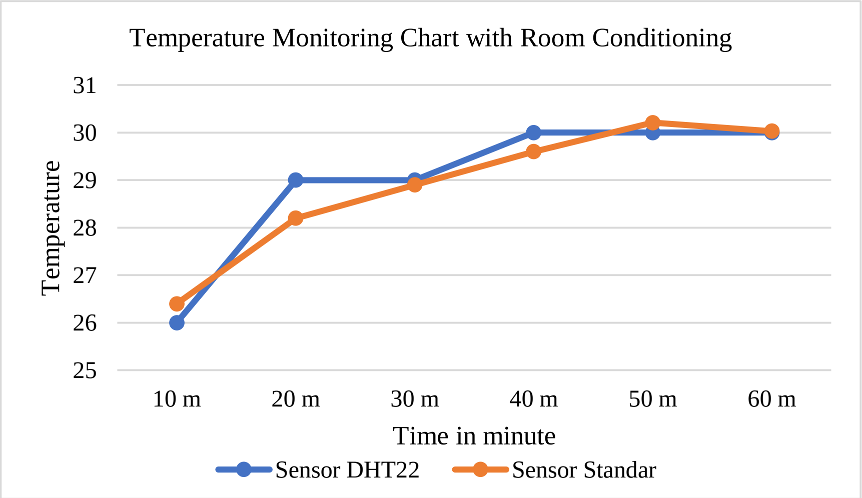


**Figure 6.** Temperature Monitoring Chart with Room Conditioning diagram

In Figure 6 the comparison process between the DHT22 sensor and the standard sensor can be observed as they both reach and stabilize at a temperature of 30 degrees Celsius. The stability is achieved approximately within one hour. Due to differences in sensor resolution, the DHT22 sensor appears to reach stability faster.

This time, I attempted to collect data with the room in an open and closed condition, representing the scenario where there is a personnel inside the room. The data collected will be used for comparison purposes.

By gathering data in both open and closed conditions, we can analyze and compare the temperature variations and stability in the presence of personnel. This comparison will provide insights into how the presence of personnel may impact the temperature inside the room and help identify any potential effects on the system's performance.

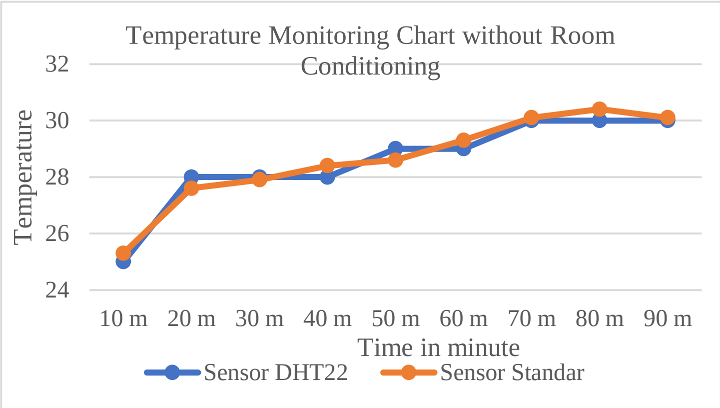


**Figure 7.** Temperature Monitoring Chart with Room Conditioning diagram

In Figure 7 it can be observed that the process of reaching stability takes longer, specifically at around the 90th minute. This delay is caused by frequent opening and closing of the calibration room, which disrupts the achievement of temperature stability during the calibration process.

From Figures 6 and 7, a comparison can be made between the calibration performed with room conditioning and without room conditioning. It is evident that in the conditioned room, the temperature calibration process reaches stability faster, taking approximately 60 minutes. On the other hand, in the non-conditioned room, the temperature calibration process takes around 90 minutes to reach stability.

This comparison highlights the impact of room conditioning on the efficiency and effectiveness of the calibration process. The conditioned room provides a more controlled environment, allowing for quicker and more consistent stabilization of temperature during calibration.

*Room Calibration Condition*

Conditioning the room is an important factor to consider during the calibration process. Therefore, the temperature and humidity conditions should be maintained to facilitate stability. Here is a table displaying the temperature and humidity readings of the room during the equipment testing.

**Table 2**. Room calibration condition

| Time (Minute) | Temperature Monitoring Chart with Room Conditioning (°C) | Temperature Monitoring Chart without Room Conditioning (°C) |
|---|---|---|
| 10 | 26,2 | 25,6 |
| 20 | 26,2 | 25,8 |

| | | |
|---|---|---|
| 30 | 26,3 | 26,5 |
| 40 | 26,3 | 27,3 |
| 50 | 26,3 | 27,3 |
| 60 | 26,3 | 26,3 |

Table 2 shows the temperature data of the calibration room, from the conditioned room and the unconditioned room. in a conditioned room where the room cannot be entered during data collection, it can be seen that the temperature is very stable and has minimal changes. whereas in the unconditioned room where the room is often opened and closed it can be seen that the room temperature has a significant change.

## CONCLUSION

The tool works well, where when the temperature during the calibration process stabilizes, the alarm will sound, and the camera detects the alarm sound. When the camera detects the alarm sound, it will send a notification to the smartphone. The performance of the designed tool is excellent. There were no significant issues during the testing. The entire system runs smoothly the camera can be used anytime and anywhere to monitor the calibration process, increasing the efficiency and effectiveness of the personnel's work. This can be seen in the comparison graph of conditioned and unconditioned rooms. In the conditioned room, personnel are not allowed to enter during the calibration process, resulting in faster stability achieved in approximately 60 minutes. In contrast, in the unconditioned room where personnel are freely moving, stability is achieved in approximately 90 minutes. During the time when personnel are not entering the room, they can utilize it for other tasks. from start to finish when in use.

## RECOMMENDATION

The system developed is a new system that has great potential for further development, such as monitoring other parameters. For example, wind speed, pressure, and rainfall. This research is currently focused on weather parameters observed by the Meteorology, Climatology, and Geophysics Agency. In the future, the system can be further expanded to broader areas, such as the industrial sector or healthcare. By expanding the system to incorporate additional parameters, it can provide a more comprehensive understanding of environmental conditions. This can be beneficial in various industries, where monitoring weather and environmental factors is crucial for operations and decision-making. Additionally, integrating the system into the healthcare sector can help monitor and predict weather-related health risks, enabling timely interventions and improved public safety. The possibilities for development are vast, and with advancements in technology and research, the system can continue to evolve and address new challenges in different domains.

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