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Implementation of DS18B20 Temperature Sensor In Esp32 And I2C LCD Based Iot Monitoring System For Mechatronics Laboratory

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Abstract: The development of Internet of Things (IoT) technology has made a significant contribution to internet-based monitoring and automation systems. In vocational education, particularly in the Mechatronics Study Program, the implementation of IoT technology is crucial to support practical activities and improve student competency in embedded systems and data communications. This research aims to design and implement an IoT-based temperature monitoring system using a DS18B20 sensor, an ESP32 microcontroller, and a local I2C LCD display. The developed system is capable of measuring temperature in real time and displaying data both on the LCD screen and via an IoT network. The research methodology included hardware design, software development, system integration, and sensor performance testing against a digital thermometer as a reference measuring instrument. Test results showed that the DS18B20 sensor has a fairly good level of accuracy with a small relative error compared to the reference measurement. This system implementation has proven to be an effective practical tool for IoT learning in the Mechatronics Laboratory. The developed system is modular, allowing for further development with the addition of other sensors and cloud platform integration

Keyword: Internet of Things, ESP32, DS18B20, Temperature Monitoring, Mechatronics Laboratory

INTRODUCTION

The development of digital technology in the Industrial Revolution 4.0 era has driven the integration of physical systems and the digital world through the Internet of Things (IoT). IoT enables various electronic devices to be interconnected via the internet, enabling automatic, real-time monitoring, data collection, and system control. This concept is the main foundation for the development of intelligent systems in various fields, such as smart homes, smart cities, industrial systems, healthcare, and technology education. The Internet of Things is essentially a network of physical devices equipped with sensors, actuators, microcontrollers, and network connectivity that enables these devices to send and receive data over the internet. With IoT, monitoring processes previously performed manually can be performed automatically and remotely. Furthermore, data generated from IoT systems can be stored and analyzed, supporting data-driven decision-making.

In engineering education, particularly in the Mechatronics Study Program, mastery of IoT technology is a key competency required for students. This is because modern mechatronic systems generally integrate various disciplines such as electronics, control systems, mechanics, programming, and data communications. Therefore, students are not only required to understand theoretical concepts but also to be able to implement these technologies in real-world systems that can be used for monitoring and control. However, during practical learning, laboratory facilities are often limited, capable of representing the implementation of IoT systems in real-world settings. Many educational laboratories still focus on basic electronics or microcontroller practicals without integrating them with network communication systems and internet-based monitoring. This situation makes it difficult for students to grasp the concept of integrating hardware and software in an IoT system as a whole. Consequently, students' understanding of integrated systems concepts is less than optimal. Furthermore, the limited availability of laboratory tools that support IoT implementation is also a barrier to project-based learning. Project-based learning methods are crucial in vocational education because they can enhance students' problem-solving skills, creativity, and technical skills in designing technological systems.

Therefore, it is necessary to develop IoT-based laboratory support tools that can be used as learning media and for student practicals. These tools are expected to provide a concrete illustration of how sensor systems, microcontrollers, data communication, and display systems work together in an integrated internet-based monitoring system. Temperature is one of the important environmental parameters to monitor in various industrial and laboratory applications. Temperature is frequently used in various processes, such as cooling system control, machine condition monitoring, laboratory environmental monitoring, and industrial automation systems. Accurate and stable temperature measurement is crucial to ensure optimal system operation. One temperature sensor widely used in embedded systems and IoT applications is the DS18B20 digital temperature sensor. This sensor offers several advantages, including a high level of accuracy, digital communication using the One-Wire protocol, measurement capabilities up to 12-bit resolution, and ease of integration with various microcontrollers. Furthermore, this sensor can be connected to several other sensors via a single communication channel, making it highly efficient in implementing monitoring systems.

In this research, a temperature monitoring system was developed using an ESP32 microcontroller as the central control. The ESP32 is a microcontroller widely used in IoT system development because it is equipped with integrated WiFi and Bluetooth communication modules. With these capabilities, the ESP32 can transmit sensor data directly over the internet, enabling real-time monitoring. To display measurement results locally, this system is also equipped with an I2C-based LCD. The use of an I2C module on the LCD provides the advantage of reducing the number of pins used on the microcontroller, resulting in a simpler and more efficient circuit. Furthermore, the LCD display allows users to view temperature values directly without having to access the system through another device.

Based on this background, this research aims to design and implemented an Internet of Things-based temperature monitoring system using a DS18B20 sensor, an ESP32 microcontroller, and an I2C LCD display. This system can be used as a practical tool in the

Mechatronics Laboratory. The developed system is expected to help students understand the concept of sensor, microcontroller, and IoT-based data communication integration in a more practical and applicable way. In addition to being a learning tool, this system is also expected to serve as a prototype for the development of IoT-based monitoring tools that can be applied to various other applications, such as laboratory environmental monitoring, electronic equipment temperature monitoring, and industrial automation systems.

METHOD

This research uses an experimental approach and system design to develop an Internet of Things (IoT)-based temperature monitoring device. The research methods include system requirements identification, hardware design, software development, system integration, and device performance testing. The designed system aims to monitor temperature in real time using digital sensors connected to a microcontroller and an internet network.

Devices Used

The hardware used in this research consists of several main components that function as sensors, data processors, and measurement display devices. These components were selected based on ease of integration, availability in the laboratory, and suitability for the Internet of Things system.

Table 1. The following table shows the components used in the research.

No	Component	Function
1	ESP32	Main Microcontroller
2	DS18B20 Sensor	Digital Temperature Sensor
3	16x2 I2C LCD	Displays Temperature Data
4	4.7kΩ Resistor	Pull-up Resistor for Sensor
5	Breadboard and Jumper	Wires Assembly Media
6	Digital Thermometer	Measurement Comparator

ESP32 Microcontroller

The ESP32 is a microcontroller developed by Espressif Systems and is widely used in IoT system development. This microcontroller has a dual-core processor with a speed of up to 240 MHz and is equipped with sufficient memory to run various embedded system applications.

DS18B20 Temperature Sensor

The DS18B20 sensor is a digital temperature sensor that uses the One-Wire communication protocol. This sensor is capable of measuring temperatures in the range of -55°C to 125°C with an accuracy of approximately ±0.5°C within a specific temperature range. One of the advantages of this sensor is its ability to use only one data line for communication, thus saving pin usage on the microcontroller.

I2C 16x2 LCD

A 16x2 LCD is used as a display medium to directly display temperature measurement results. This LCD module uses I2C (Inter-Integrated Circuit) communication, allowing data communication with the microcontroller using only two main lines: SDA (Serial Data) and SCL (Serial Clock).

Digital Thermometer

A digital thermometer is used as a reference measurement tool to evaluate the accuracy of the measurement results obtained from the DS18B20 sensor. By comparing the values obtained from the sensor and the reference measuring tool, the error level of the developed system can be determined.

System Design

System design was carried out to integrate all hardware and software components to create an IoT-based temperature monitoring system that works in an integrated manner. In general, the system developed consists of several main components: a temperature sensor, a microcontroller, a local display system, and an internet-based data communication system.
The temperature monitoring system consists of several main components:

1. DS18B20 temperature sensor
2. ESP32 microcontroller
3. I2C LCD as local display
4. IoT communication system

Temperature Sensor

The DS18B20 sensor functions as the primary device for detecting and measuring environmental temperature. This sensor reads the temperature value and then sends the data in the form of a digital signal to the microcontroller via the One-Wire communication protocol.

The ESP32 microcontroller serves as the main processing unit in the monitoring system. This microcontroller receives temperature data from the DS18B20 sensor, then processes the data before displaying it on the LCD and sending it over the internet.

In addition, the ESP32 also runs a program that manages the communication process between the sensor, display system, and IoT network.

Local Display System

An I2C LCD is used to display temperature values directly on the device. With this local display, users can view temperature measurement results in real time without having to open an internet-based monitoring application.

IoT Communication System

The IoT communication system allows temperature data measured by the sensor to be transmitted over the internet for remote monitoring. The ESP32 uses a WiFi connection to send sensor data to the IoT monitoring platform. Data transmitted over the internet can be stored and further analyzed for monitoring and research purposes.

Overall, the system designed in this research is capable of integrated temperature measurement, data processing, local display, and data transmission over the internet. This system is expected to be used as a practical tool in the Mechatronics Laboratory, enabling students to better understand the concept of implementing the Internet of Things.

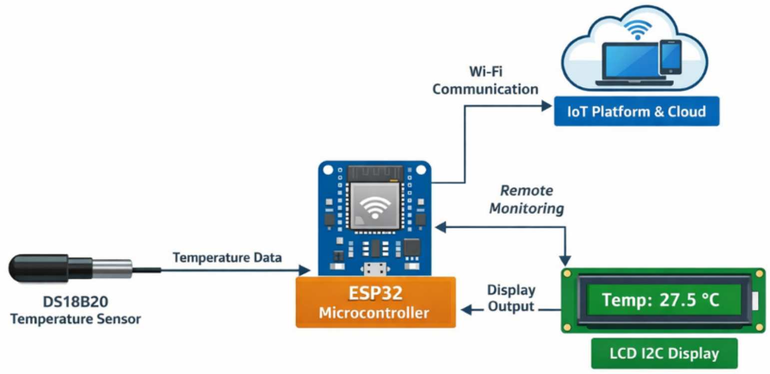

Figure 1. Block Diagram of the IoT Monitoring System

System Operation Principle

The operating principle of the temperature monitoring system in this study is based on the process of sensor data acquisition, data processing by a microcontroller, and data presentation and transmission via a display system and internet network. The system is designed to perform real-time temperature monitoring by utilizing digital sensors and Internet of Things-based network communications. In general, the system consists of several main components: a temperature sensor, a microcontroller, a local display system, and a network communications system. All these components work in an integrated manner, resulting in a stable and easy-to-use temperature monitoring system for practical activities in the Mechatronics Laboratory.

The workflow of the temperature monitoring system can be explained as follows:

1. Temperature Reading by the DS18B20 Sensor

The first stage in the system's operation is the process of reading the ambient temperature by the DS18B20 sensor. This sensor detects changes in the surrounding temperature and then converts it into a digital signal. Unlike analog temperature sensors, which require signal conversion using an ADC (Analog to Digital Converter), the DS18B20 sensor is equipped with an internal digital conversion system, so the temperature data generated is directly digital.

2. Data Transmission via One-Wire Protocol

After the sensor measures the temperature, the data is then sent to the microcontroller using the One-Wire communication protocol. This protocol allows data communication to use only one data cable in addition to the voltage and ground lines. The advantage of the One-Wire protocol is its ability to connect multiple sensors on the same communication line. Each DS18B20 sensor has a unique identification code (64-bit address) so the microcontroller can distinguish each sensor connected to the network.

3. Data Processing by the ESP32 Microcontroller

After receiving temperature data from the sensor, the ESP32 microcontroller will process the data. This stage includes reading the digital data from the sensor, converting the temperature value into a displayable format, and processing the data before sending it to other devices.

Programs on the ESP32 are developed using the Arduino IDE, utilizing DS18B20 sensor communication libraries such as DallasTemperature and OneWire. These libraries simplify communication between the microcontroller and the sensor, allowing for more accurate and stable temperature readings.

4. Displaying Data on an I2C LCD

After the temperature data is processed by the microcontroller, the measurement results are displayed on a 16x2 I2C-based LCD. This LCD serves as a local display, allowing users to view the temperature measurements directly on the device. The use of an I2C module on the LCD offers the advantage of simplified wiring, as it only requires two communication lines: SDA (Serial Data) and SCL (Serial Clock). This reduces the number of pins used on the microcontroller, resulting in more efficient system circuitry.

5. Sending Data Over the Internet

In addition to being displayed on the LCD, temperature data can also be sent over the internet using the ESP32's WiFi connection. This network communication capability allows the temperature monitoring system to be accessed remotely via an IoT platform.

This IoT-based monitoring system offers several advantages, including:

a. Enables temperature monitoring from different locations
b. Supports automatic data recording
c. Facilitates data analysis for research or system development

6. IoT Monitoring System Integration

Overall, the system developed in this research works through sensor data acquisition, data processing by a microcontroller, local data display, and data transmission over the internet. The integration of all these components results in a simple yet effective IoT-based temperature monitoring system. This system is expected to be used as a learning tool for Internet of Things practicals in the Mechatronics Laboratory, allowing students to directly understand the integration of sensors, microcontrollers, and network communication systems into an IoT-based monitoring system.

Data collection

Data collection was conducted through experimental testing by comparing the DS18B20 sensor readings with a reference digital thermometer.

Testing Procedure:

1. The sensor was placed in a laboratory environment.
2. Measurements were taken 10 times.
3. The measurement results were compared with those of a digital thermometer.
4. The measurement error was calculated.

DS18B20 Temperature Sensor Testing

Table 2. DS18B20 Temperature Sensor Testing

No	Solder		Hot water	
	Digital Thermometer (ºC)	**Temperature Sensor DS18B20 (ºC)**	**Digital Thermometer (ºC)**	**Temperature Sensor DS18B20 (ºC)**
1	32.6	31.5	49.5	48.56
2	34.8	34.5	59.5	54.44
3	39.4	36.06	62.3	56.44
4	44.8	37.62	65	60.75
5	56.6	44.21	66.6	65.5
6	63.7	49.62	67.5	66.2
7	79.3	54.3	72.3	71.5
8	91,4	60.62	82.3	80.8
9	97.5	65.88	88.2	87.3
10	100.7	69.62	96.5	92.8

RESULTS AND DISCUSSION

1. System Implementation

System implementation was carried out after the hardware and software design processes were completed. This stage aimed to integrate all designed components so that the Internet of Things (IoT)-based temperature monitoring system could function optimally. Implementation included assembling the hardware circuit, developing the program on the ESP32 microcontroller, and testing the overall system. In the hardware implementation stage, the DS18B20 temperature sensor was connected to the ESP32 microcontroller via a One-Wire communication channel. The sensor data line is connected to one of the digital pins on the ESP32 and equipped with a 4.7 kΩ pull-up resistor to maintain data communication stability.

Next, an I2C-based 16x2 LCD module is connected to the ESP32 using the SDA and SCL communication lines, enabling direct temperature data display on the device.

The software implementation process was carried out using the Arduino IDE as a programming environment for the ESP32 microcontroller. The developed program reads temperature data from the DS18B20 sensor using the OneWire and DallasTemperature libraries. The obtained temperature data is then processed by the microcontroller to be displayed on the LCD screen and sent over the internet using the WiFi module on the ESP32.

The system implementation results show that the developed device is capable of real-time temperature monitoring via the DS18B20 sensor. The sensor periodically reads the ambient temperature and sends the data to the microcontroller for processing. The processed temperature value is then displayed on the 16x2 LCD screen, allowing users to directly view the ambient temperature conditions locally without the need for additional devices.

In addition to being displayed on the LCD, temperature data can also be integrated with an Internet of Things system via the ESP32's WiFi network connection. This connectivity allows measurement data to be sent to an IoT-based monitoring platform, enabling remote monitoring using devices such as a computer, laptop, or smartphone. The implementation of this system demonstrates that the integration of the DS18B20 temperature sensor, ESP32 microcontroller, and LCD display module can work effectively to create a simple yet effective temperature monitoring system. The developed system also has the potential for further development by adding data storage (data logging), cloud-based data analysis, and integration with an automatic control system.

Therefore, the device developed in this research not only functions as a temperature monitoring system but can also be used as a learning tool for Internet of Things practicals in the Mechatronics Laboratory. Through this tool, students can learn firsthand how sensors, microcontrollers, display systems, and internet-based data communications are integrated into an IoT system.

2. Heating Conditions with a Soldering Iron

In experiments with a soldering iron heat source, the reference temperature gradually increased from approximately 32.6°C to 100.7°C. The DS18B20 sensor followed this increasing temperature trend, but tended to show lower readings. For example, in the first experiment, the difference was relatively small (32.6°C vs. 31.5°C), but in the final experiment, the difference widened (100.7°C vs. 69.6°C). This indicates a limitation of the DS18B20 in responding quickly to high temperatures, or a possible delay in heat transfer due to the sensor's contact method.

In general, error increases with increasing temperature, which can be caused by:

a. Sensor thermal capacity: The DS18B20 takes longer to adjust to rapid temperature changes.
b. Mounting position: If the sensor is not placed tightly against the heat source, a significant difference can occur between the actual temperature and the sensor's measured temperature.

3. Hot Water Conditions

In testing with hot water, the reference temperature range was 49.5°C to 96.5°C, while the DS18B20 recorded values of 48.6°C to 92.8°C. Generally, the difference between the sensor and the reference was within 2–4°C. This indicates that the DS18B20 performs well in liquid media, as heat transfer is more even compared to heating with a soldering iron. Accuracy is increased because the sensor's contact with the water provides direct conductive heat transfer. The following chart compares the Digital Thermometer with the DS18B20 Sensor under two test conditions.

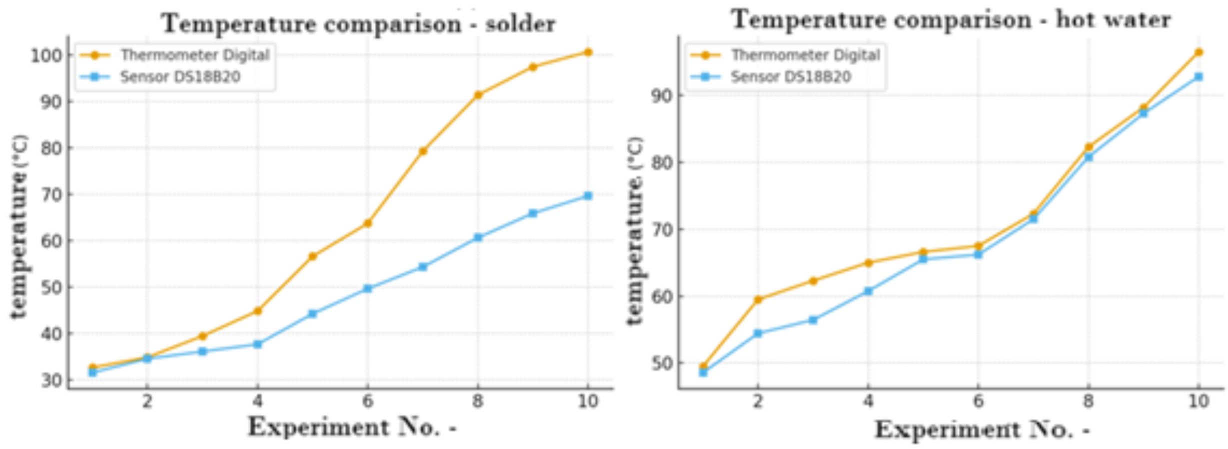

Figure 2. Comparison Chart of Digital Thermometer vs. DS18B20

a. Soldering → Larger deviations are seen at higher temperatures, with the DS18B20 tending to read lower.
b. Hot Water → The DS18B20 readings are quite close to the reference, with a small difference (±2–4 °C).

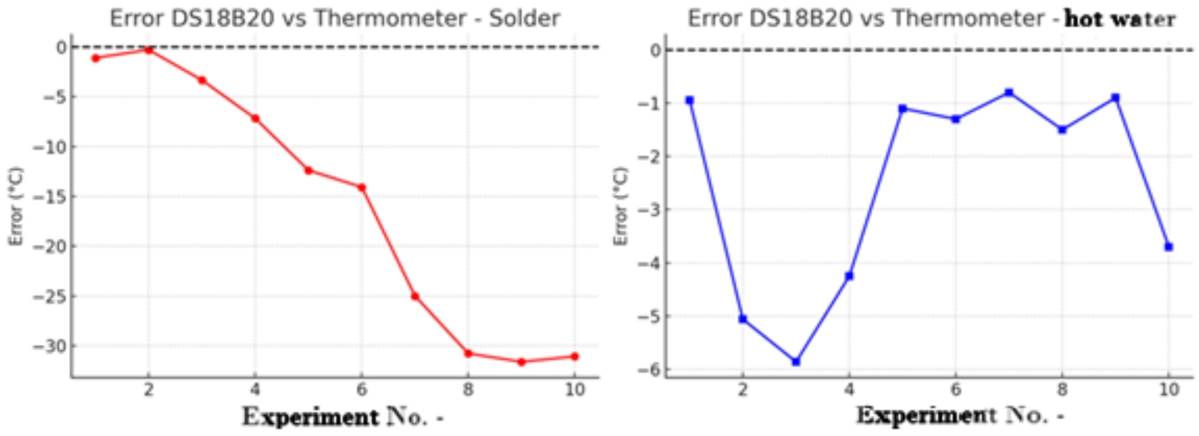

Figure 3. Error Graph of Digital Thermometer vs DS18B20

CONCLUSION

Based on the research results, it can be concluded that:

1. The ESP32-based temperature monitoring system and DS18B20 sensor were successfully designed and implemented.
2. The system is capable of displaying real-time temperature data via an I2C LCD and can be integrated with an IoT platform.
3. Test results show that the DS18B20 sensor has a good level of accuracy with relatively small errors compared to a digital thermometer.
4. The developed system can be used as a practical tool in the IoT Laboratory of the Mechatronics Study Program.

Furthermore, the development can be carried out by adding other sensors such as humidity, gas, or light sensors to build a more comprehensive environmental monitoring system.

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