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Research Article

Design and Simulation of an Automatic Temperature-Based Air Conditioner Control System Using ATmega16

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Abstract: Technology is developing rapidly, especially in the field of electronics. One of its applications is a microcontroller-based automatic control system to improve efficiency and comfort in room temperature regulation. This study aims to design and simulate an automatic air conditioning control system based on temperature using the ATmega16 microcontroller. The LM35 sensor is used to measure room temperature, and the data is processed by the ATmega16 through its internal ADC feature. The measured temperature is displayed on a 16x2 LCD, and the system activates or deactivates the AC through a relay circuit according to predefined temperature thresholds. The research method includes circuit design using Proteus and programming with Microchip Studio. Based on simulation results, the system can accurately read temperature values and control the AC automatically according to the set conditions. These results indicate that the designed system works properly and has potential as a microcontroller-based automatic air conditioning control solution.

Keywords: ATmega16; Automatic Air Conditioner Control; Embedded System; Microcontroller; Temperature Sensor.

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1. Introduction

The development of electronic technology and embedded systems has progressed rapidly over the past few decades (Rismayadi et al., 2024; Syahrul et al., 2024). This advancement has led to the creation of various automation systems that are widely used in everyday life (Ak & Viena, 2021; Pramudita et al., 2024). One of the most commonly developed automation applications is an automatic room temperature control system. Proper temperature regulation is essential to maintain environmental comfort in residential buildings, offices, and public spaces (Abdillah et al., 2024).

Air Conditioner (AC) units are widely used to maintain stable room temperatures (Ismail et al., 2024). However, in practice, AC operation is still often performed manually without considering real-time environmental temperature changes (Afika et al., n.d.; Palaha et al., 2021). This condition results in inefficient system performance because the AC may continue to operate even when the room temperature has already reached a comfortable level, or it may turn on too late when the temperature increases. Therefore, an automatic control system is required to adjust AC performance based on real-time room temperature conditions (Aulia et al., 2021).

Microcontroller-based control systems provide an effective solution because they are capable of reading data from sensors, processing information, and generating control decisions in a short time (Ulum et al., 2025). ATmega16 is one of the widely used microcontrollers in control system development due to its internal ADC feature, sufficient number of I/O pins, and ease of programming. By utilizing a temperature sensor and an actuator circuit such as a relay, a system can be designed to automatically turn the AC on or off according to predetermined temperature limits.

Previous studies have implemented microcontroller-based temperature monitoring and control systems; however, most of them focus primarily on data reading and display functions without quantitatively analyzing the characteristics of ADC conversion, the stability of actuator control logic, and the linear relationship between temperature changes and the digital values generated by the conversion process (Manihuruk & Sibarani, 2022). In addition, several studies use digital temperature sensors such as DHT11, which have limited resolution and relatively slower response compared to precision analog sensors (Ivory, 2021).

This research addresses these limitations by designing an automatic air conditioning control system based on the ATmega16 microcontroller that utilizes a 10-bit internal ADC to analyze the linear relationship between the analog output of the LM35 temperature sensor and the digital conversion value. In addition, a structured temperature threshold is implemented to reduce the possibility of repeated switching in the relay. Therefore, the main contribution of this research lies not only in the implementation of an automatic control system but also in the evaluation of ADC conversion performance and the stability of control logic in a microcontroller-based embedded system.

Based on these problems, this study aims to design and simulate an automatic air conditioning control system based on room temperature using the ATmega16 microcontroller. The system is designed to read temperature using a sensor, display the measurement results on an LCD, and control the AC using a relay based on predetermined temperature thresholds. The simulation is carried out using the Proteus software to ensure that the system operates according to the design.

This research is expected to contribute to the development of integrated and easily implemented microcontroller-based room automation systems. In addition, the results of this study can serve as a basis for further development toward real hardware implementation with improved system efficiency and stability.

2. Literature Review

Automatic Control System

An automatic control system is a system that operates by utilizing input, processing, and output without direct human intervention (Prasetyo et al., 2023). In a temperature control system, a sensor is used as an input device to detect changes in environmental temperature (Abdurrohman, 2023). The data obtained from the sensor is then processed by a controller to determine the appropriate action for the actuator. In this research, the control system is used to determine the operating condition of the air conditioner based on predetermined temperature thresholds.

Atmega16 Microcontroller

ATmega16 is an 8-bit microcontroller based on the AVR architecture that features 16 KB of flash memory, 32 I/O pins, and several internal modules such as ADC, timers, and serial communication (Agustus, 2024). One of the main advantages of ATmega16 in this research is the availability of a 10-bit internal ADC, which allows the conversion of analog signals from the temperature sensor into digital data without requiring additional external circuits. In this system, the microcontroller functions as the main data processing unit and control center (Shodiq et al., 2021).

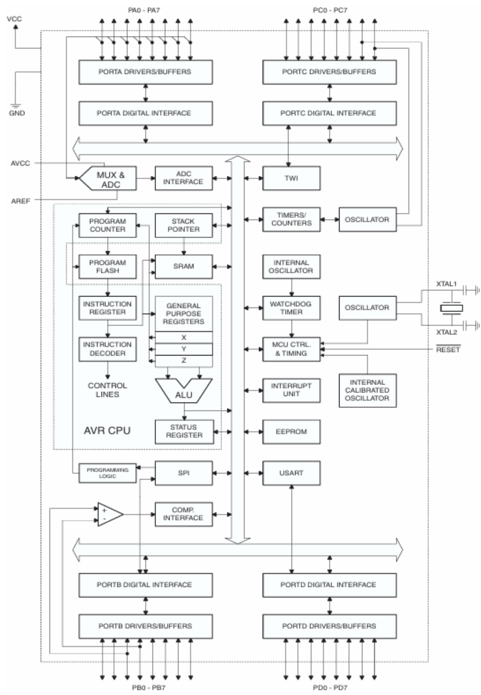

Figure 1. Atmega16 Block Diagram.

LM35 Temperature Sensor

The LM35 is an analog temperature sensor that produces an output voltage linearly proportional to temperature changes, with a characteristic of 10 mV for every 1°C increase (Hadi et al., 2022). This sensor operates within a wide temperature range and provides a relatively high level of accuracy for room temperature control applications. In this research, the LM35 is used as an input device to detect environmental temperature, which is then converted into digital data by the ADC in the ATmega16.

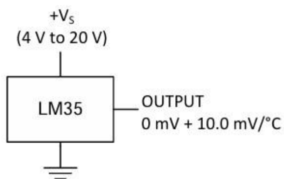

Figure 2. LM35 Temperature Sensor.

Analog-to-Digital Converter (ADC)

An Analog-to-Digital Converter (ADC) is a module used to convert analog signals into digital data so that they can be processed by a microcontroller (Cahyadi et al., 2023). The ATmega16 has a 10-bit internal ADC that allows voltage readings within a certain range to be converted into numerical data. The ADC conversion results are then used as the basis for decision-making in the automatic air conditioner control system.

Relay

A relay is an electronic component that functions as an electrically controlled switch (Prasetiyanto & Hadisusila, 2023). The relay will be activated or deactivated based on the ADC conversion results received from the ATmega16. In this system, the relay is used to connect and disconnect the power supply to the air conditioner according to the detected temperature conditions.

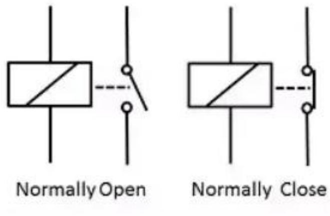

Figure 3. Relay Symbol (Normally Open and Normally Closed).

LCD 16x2 (Liquid Crystal Display)

The 16x2 LCD is used as a display medium to show the temperature value in real time. This module is capable of displaying alphanumeric characters and can be easily integrated with a microcontroller using either 4-bit or 8-bit mode (Bramudiansyah, n.d.). In this research, the LCD functions as a monitoring device to provide temperature information to the user.

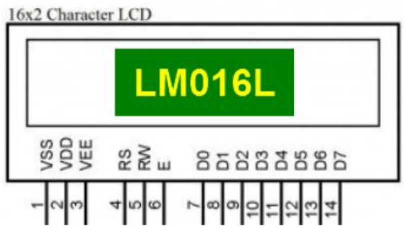

Figure 4. 16x2 LCD Configuration

3. Proposed Method

This study applies a design-based research method and simulation of a microcontroller-based control system. The approach used in this research is experimental through circuit design and virtual system testing using simulation software. The research focuses on the design, testing, and performance analysis of an automatic air conditioner control system based on room temperature.

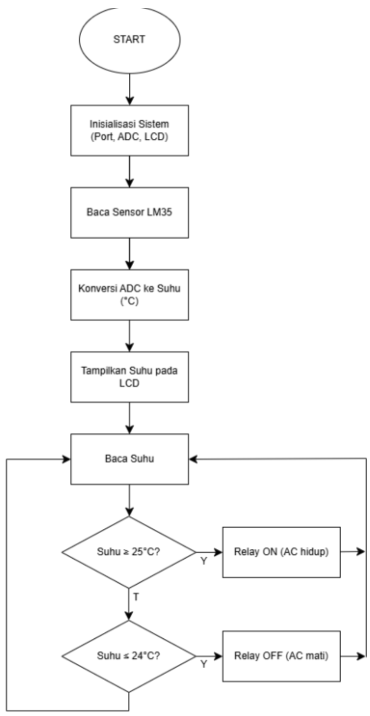

Figure 5. Flowchart of the Automatic Air Conditioner Control System.

The system operation begins with system initialization, including the configuration of input/output ports, the ADC module, and the LCD. After initialization, the microcontroller reads temperature data from the LM35 sensor. The analog signal obtained from the sensor is then converted into digital data using the internal ADC of the ATmega16 and processed into temperature values in degrees Celsius (°C). The measured temperature values are displayed on the LCD as real-time information about room temperature conditions.

After the temperature is obtained, the system performs a decision-making process based on predefined temperature thresholds. If the temperature is greater than or equal to 25°C, the microcontroller activates the relay, and the air conditioner turns on. Conversely, if the temperature is less than or equal to 24°C, the relay is deactivated, and the air conditioner turns off. This process runs continuously in a loop to ensure that the room temperature remains within the desired range. With this mechanism, the system is able to operate automatically and respond to environmental temperature changes.

Hardware Design

Overall Circuit Design

To provide a clearer understanding of the automatic air conditioner control system based on the ATmega16 microcontroller, the overall circuit design is illustrated in the system schematic. The microcontroller functions as the main controller that processes input data from the temperature sensor and controls the output components such as the LCD and relay.

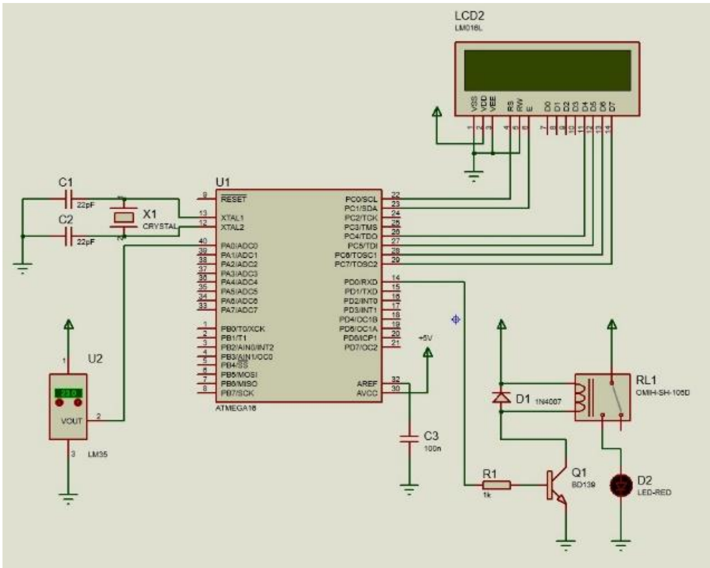

Figure 6. Overall Circuit Design.

Minimum System Circuit

A 5V power supply is provided to the VCC and AVCC pins as the main voltage source of the microcontroller, while the AREF pin is connected to a 100 nF capacitor to ground as the ADC reference voltage to obtain more stable temperature readings. With this configuration, the microcontroller can operate stably and is ready to perform temperature reading and system control processes.

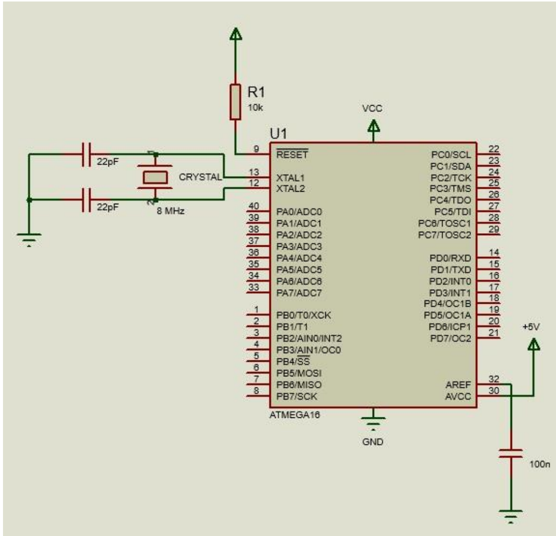

Figure 7. Atmega16 Minimum System.

LM35 Sensor Circuit

The LM35 sensor circuit is connected to port A0, which corresponds to ADC channel 0. The sensor operates using a 5V power supply. The analog voltage output generated by the LM35 is proportional to the temperature and is then converted into digital data by the ADC in the ATmega16.

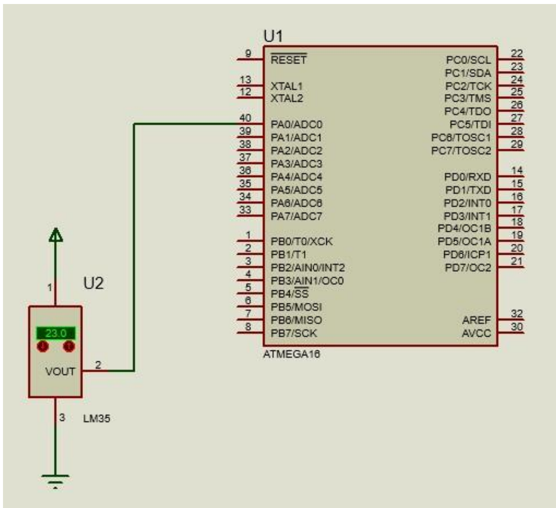

Figure 8. LM35 Sensor Circuit.

LCD Circuit

The LCD circuit uses a 16x2 LCD module that functions to display the temperature value obtained from the sensor. The VSS pin is connected to ground, and the VDD pin is connected to +5V as the power supply. The VEE pin is connected to ground to adjust the display contrast in the simulation. The RS and E pins are connected to the microcontroller as control pins, while the RW pin is connected to ground so that the LCD operates in write mode. The data lines used are D4–D7; therefore, the LCD operates in 4-bit mode to reduce the number of I/O pins used.

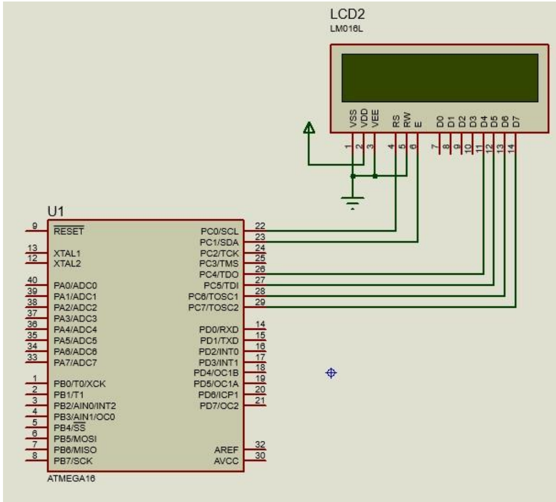

Figure 9. LCD LM016L (16×2) Circuit.

Relay Circuit

The relay circuit in the automatic air conditioner control system functions as an electronic switch that connects or disconnects the AC power supply. The relay is controlled by the microcontroller based on the temperature values read from the sensor. When the temperature is greater than or equal to 25°C, the relay is activated and the air conditioner turns on. When the temperature is less than or equal to 24°C, the relay is deactivated and the air conditioner turns off.

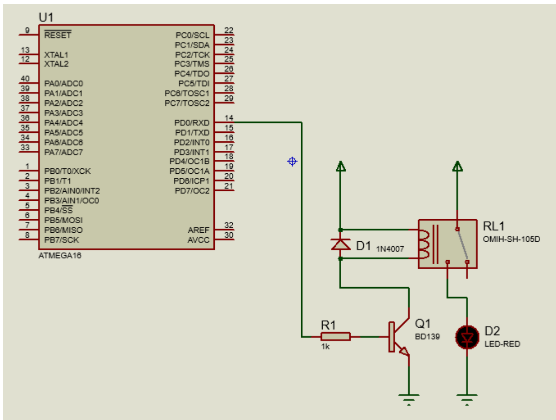

Figure 10. Relay Circuit.

Software Design

The software used to program the ATmega16 microcontroller is Microchip Studio using the C/C++ programming language. This software is used to write, edit, and compile the program until a .hex file is generated, which is then loaded into the microcontroller in the Proteus simulation. Microchip Studio also facilitates the configuration of system parameters such as clock frequency and I/O port settings.

Figure 11. Microchip Studio Start Program Menu.

The program is designed to read temperature values from the LM35 sensor through the ADC module. The temperature data is then processed and displayed on the LCD, followed by a decision-making process to control the relay according to the predefined temperature thresholds.

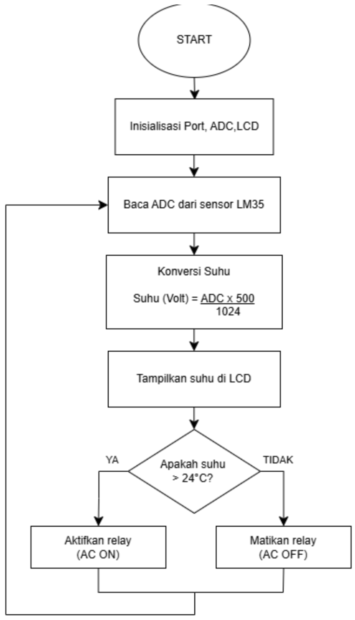

Figure 12. Flowchart of the Temperature Reading Program.

4. Results and Discussion

The automatic air conditioner control system based on the ATmega16 microcontroller has been successfully designed as the main controller that activates and deactivates the air conditioner based on temperature readings obtained from the LM35 sensor. The testing results show that the system operates according to the design and is effective in controlling the air conditioner in the simulation environment. The temperature readings obtained from the sensor and displayed on the LCD are presented in the testing table.

Table 1. Testing Result.

Temperature (°C)	ADC Value	Relay Status
19	41	OFF
20	42	OFF
21	43	OFF
22	45	OFF
23	47	OFF
24	49	OFF
25	51	ON
26	53	ON
27	55	ON

28	57	ON
29	59	ON
30	61	ON

The ATmega uses a 10-bit ADC with a voltage range of 0–5 V; therefore, the ADC resolution can be calculated as follows:

$$\boldsymbol{Resolusi\ ADC = \frac{5V}{1024} = 4,88\ mV}$$

The LM35 sensor produces an output voltage of 10 mV for every 1°C increase in temperature. Therefore, a temperature change of 1°C will result in a change of approximately two ADC units. This is consistent with the testing results shown in Table 1, where every 1°C increase in temperature is followed by an increase of approximately two ADC values. These results indicate that the analog-to-digital conversion process in the ATmega16 operates properly and is consistent with the characteristics of the LM35 sensor.

Based on the testing results, the ADC value increases along with the increase in temperature detected by the LM35 sensor. This relationship indicates that the ADC-to-temperature conversion system operates properly and is consistent with the characteristics of the sensor used. In addition, the relationship between ADC values and temperature shows a linear characteristic, which can be seen from the consistent increase in ADC values for every increase in temperature.

At temperatures between 19°C and 24°C, the relay status remains in the OFF condition because the temperature has not exceeded the predefined threshold. When the temperature reaches 25°C to 30°C, the relay changes to ON, indicating that the air conditioner is automatically activated. This result is consistent with the program logic that applies a temperature of ≥ 25°C as the condition for activating the air conditioner. The control system also shows consistency in decision-making, where the relay will only be activated when the temperature reaches the specified limit and remains in the OFF condition when the temperature is below the threshold.

These findings are consistent with previous studies that implemented the ATmega16 microcontroller as a temperature data processing unit using analog sensors, which reported that a 10-bit ADC resolution is capable of representing changes in sensor voltage linearly within a certain measurement range (Manihuruk & Sibarani, 2022). This result shows that the analog-to-digital conversion system in the ATmega16 has sufficient stability and accuracy for temperature control applications.

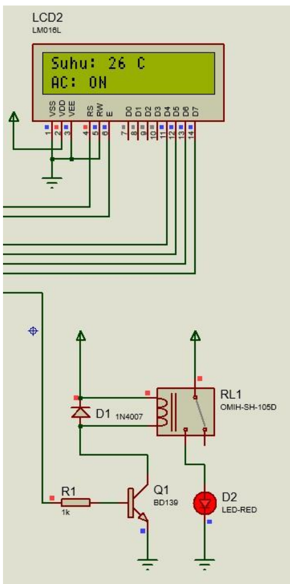

Figure 13. Temperature Condition ≥ 25°C (AC ON).

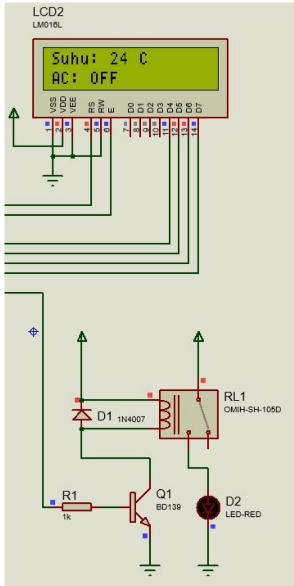

Figure 14. Temperature Condition ≤ 24°C (AC OFF).

Based on the testing results and analysis that have been carried out, the designed system is not only able to read temperature values and control the air conditioner automatically but also shows a linear relationship between temperature and ADC values as well as stable relay control logic. Although the system works properly in the simulation stage, the testing is still limited to a virtual environment and has not yet represented real conditions such as rapid environmental temperature changes and noise effects on sensor readings. Therefore, real hardware implementation is still required to evaluate the overall system performance more comprehensively

5. Conclusions

Based on the research results, it can be concluded that the automatic air conditioner control system has been successfully designed and simulated using the ATmega16 microcontroller as the main controller, the LM35 sensor as the temperature input, a 16x2 LCD as the monitoring display, and a relay as the actuator for controlling the air conditioner. The temperature reading process using the 10-bit internal ADC of the ATmega16 operates properly and shows a linear relationship between the ADC values and temperature in accordance with the characteristics of the LM35 sensor.

The system is able to automatically activate the air conditioner at temperatures ≥ 25°C and deactivate it at temperatures ≤ 24°C according to the program logic that has been designed. This result indicates that the control system works automatically and responds well to temperature changes. The system is still limited to the simulation stage and can be further developed through real hardware implementation and the addition of a more stable control method in future research.

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