Implementation of Microcontroller-Based Electrical Room Control System

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ABSTRACT

The implementation of a microcontroller-based electrical room control system aims to provide an automation solution in managing electricity usage in a room. This system uses an Arduino Uno microcontroller integrated with a timer to automatically set the on and off time for electrical equipment, such as lights, fans, and computers, according to a schedule determined by the user. In addition, this system is equipped with an SMS notification feature that provides information regarding the operational status of components, such as notifying if a device is not functioning properly or is damaged. The test method shows that this system can set the time accurately, with most tests successfully turning electrical devices on or off according to the set schedule. However, there are several situations where delays or errors in operation occur, indicating the need for further evaluation in terms of timing and system programming. However, the SMS feature makes it easy for users to monitor the status of electrical equipment, so that they can immediately take action if a disruption occurs. The implementation of this system is expected to not only increase the efficiency of energy use, but also help in saving operational costs and managing rooms more efficiently. With automation in electrical control, this system provides comfort and security, and reduces the risk of energy waste caused by uncontrolled use of electrical equipment. This microcontroller-based electrical room control system has great potential to be implemented on various scales, from households to use in commercial and industrial areas.

Keywords: Electrical Control System, Arduino Microcontroller, Timer, SMS, Energy Saving.

Introduction

In this rapidly developing digital and globalization 4.0 era, the need for efficient, intelligent, and integrated technology is increasing. One important aspect of everyday life is the use of electricity, which is a primary need for every household and industry. Therefore, efficient control and monitoring of electricity usage is very important to support sustainability and energy savings. In this case, microcontroller-based control system technology offers a smart and affordable solution to monitor and control electricity usage indoors, as well as optimize its performance to be more efficient.

Along with the rapid development of technology, especially in the field of information and communication technology, microcontroller-based control and monitoring systems are one of the important innovations in industry 4.0. This system allows devices to communicate automatically and regulate electricity consumption using sensors and digital devices connected via a network. This technology makes it easy for users to control electrical devices using computer applications or mobile devices such as smartphones. This is of course very relevant to the lifestyle of modern society which is increasingly dependent on mobile technology.

According to Airlangga Hartarto as quoted in Ely Djulia's book, industry 4.0 relies on the internet and communication technology to accelerate the production process, with increasingly intelligent and automatic control systems. The use of this technology is not only limited to industry, but can also be applied in everyday life, especially in managing electrical energy in households. An efficient control system can help regulate electricity consumption in various locations with different needs, thereby reducing energy waste and saving operational costs. Although this technology has many benefits, the application of control and monitoring systems is still limited to the industrial scale and has not been widely applied in household life. In fact, with easy access to smart devices and mobile applications, people now find it easier to control their electrical devices more efficiently. Therefore, this study aims to develop a microcontroller-based electricity usage control and monitoring system that can be applied to households to improve energy efficiency and make it easier for users to manage electricity consumption.

This research will examine the implementation of an electrical room control and monitoring system using a microcontroller as a solution to manage electricity usage more efficiently and environmentally friendly. Thus, this system will not only provide convenience for users in controlling electrical devices, but also contribute to reducing energy consumption and increasing sustainability in the future.

Formulation of the problem:

1) How to design and implement a microcontroller-based control system that can optimize the use of electrical energy in a room?
2) How does this system detect and turn off unused electrical devices to reduce energy waste?

Literature Review

A. Control and Monitoring System

A control system is a system designed to receive input or commands, process them, and produce output that is in accordance with the desired objectives. Control systems can be divided into two types, namely open-loop control systems and closed-loop control systems. Closed-loop control systems use feedback to ensure that the system output matches the desired input, making it more efficient in energy control.

In the context of electrical energy use, control and monitoring systems play an important role in managing electricity consumption, especially in households and buildings that require more efficient energy management. The monitoring system functions to monitor electrical energy usage in real-time, while the control system regulates the flow of energy based on the data obtained. The use of this technology allows for significant energy savings and helps reduce unnecessary operational costs.

B. Microcontroller in Control System

Microcontrollers are the main components in digital-based control systems. Microcontrollers have the ability to process input signals, control output devices, and communicate with other devices through various interfaces (I/O). Microcontrollers have become the primary choice in various automation applications due to their relatively low cost, high flexibility, and ability to be integrated with various sensors and actuators. One of the most popular microcontroller applications is in electrical control systems. The use of microcontrollers in electrical system control allows automatic control of devices through data processing from sensors and system feedback (Wahid, 2018). By using microcontrollers, control systems can function more precisely and responsively to real conditions in the field, such as regulating electrical power or monitoring energy consumption.

C. Use of Microcontroller-Based Control Systems in Electrical Energy Management

The use of microcontroller-based control systems to manage electricity usage has been implemented on various scales, both in households, offices, and industries. This technology allows users to monitor energy consumption in real-time and make wiser decisions regarding electricity usage (Sofiana & Yuliana, 2019). By utilizing power sensors and microcontrollers, the system can detect energy waste and take necessary actions, such as turning off unused devices or adjusting power consumption based on needs. Several studies related to the implementation of this control system have shown positive results. For example, research conducted by Purnomo and Wibowo (2020) showed that by using a microcontroller, the control system they designed managed to save electricity consumption by up to 30% in households with more efficient device settings. The use of microcontroller-based devices enables intelligent and automatic energy management, which ultimately helps reduce electricity loads and increase energy efficiency.

a. Real Time Clock (RTC) DS1307

Real Time Clock (RTC) DS1307 is a chip (IC) that functions to store time and date accurately. RTC DS1307 can record time data such as seconds, minutes, hours, date, month, day of the week, and year, with validity up to The chip is equipped with 56-byte non-volatile (NV) RAM that functions to store data even when the power is turned off, thanks to the power backup from the battery.

The RTC DS1307 uses an I2C (Two-wire) serial interface that allows communication with a microcontroller or other device using two data lines, namely SDA (Serial Data) and SCL (Serial Clock). Additional features owned by this chip include programmable square wave signal output and automatic power-fail detection, which is useful for setting the system to continue running or restart automatically in the event of a power failure.

Figure 1. Real Time Clock

In terms of power consumption, the DS1307 RTC is highly efficient with power consumption of less than 500nA when operating in battery backup mode, making it ideal for applications that require energy savings. In addition, this chip is also designed for use in a wide range of environmental conditions with excellent temperature resistance, namely between -40°C to +85°C, making it suitable for use in industrial applications and devices operating in extreme environments.

b. SIM800L: GSM/GPRS Module for Arduino

SIM800L is one of the popular serial GSM/GPRS modules and is widely used in various microcontroller-based projects, such as Arduino and AVR. This module allows devices to connect to GSM/GPRS networks, so that they can perform various communication functions such as sending SMS messages, making voice calls, and connecting to the internet using GPRS data connections. The SIM800L module is a mini version of the GSM module that uses Micro SIM as a SIM card.

Figure 2. GSM/ GPRS SIM 800L module

The advantage of SIM800L lies in its small physical size, making it very suitable for projects with limited space. This module is also equipped with a UART serial interface that facilitates communication between the module and the microcontroller, and can be used in IoT applications, remote monitoring systems, and device control via SMS.

c. DC to DC Converter: Lowers or Increases DC Voltage

The DC to DC Converter module functions to reduce the DC voltage from a power source with a higher input range to a lower output voltage, with a maximum current capacity of up to 3A. This converter can reduce the voltage in the range of 3.2V to 4.6V, with a difference between the input and output voltages of no more than 1.5V DC. This technology is very useful when we need the right voltage to support electronic devices, such as in applications that use battery power.

Figure 3. Converter Step Down Power Supply Module

Basically, DC to DC converter is used to adjust the voltage in electronic circuits that require DC current with a certain voltage value, such as current from a battery. One of the main reasons why a DC to DC converter is needed is to lower or raise the voltage as needed, with higher efficiency compared to using simple components such as resistors.

Research Method

Block diagram planning is the first stage in designing and compiling a circuit. Explanation of the information and function of the following circuit block diagram:

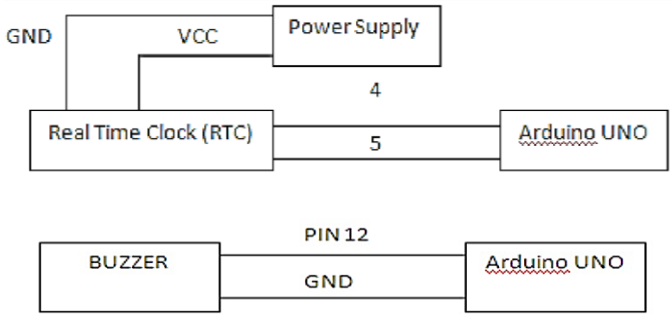

Figure 4. Real Time Clock (RTC) Circuit Block Diagram

This study aims to design and implement a timer based on the Arduino UNO microcontroller that functions as an electrical control controller using the Relay module. The following are the steps and procedures used in this study.

a. Timer System Design

In this timer system design, two pins are used on the Arduino UNO, namely A4 and A5 as control pins for the electrical control system. Pins A4 and A5 are connected to the Relay module which will control the flow of electricity to the connected device. These two pins act as digital outputs to activate or deactivate the relay based on commands given by the microcontroller.

b. Power Supply Connection

To ensure the system runs properly, the power supply connection is made by utilizing the GND and VCC pins on the timer circuit.

1). The GND pin on the Arduino UNO is connected to ground on the power supply, to ensure the circuit has a proper reference to the voltage.

2). The VCC pin on the Arduino UNO is connected to the positive (+) pin of the power supply with a voltage of 5V, to provide the power required by the microcontroller and other components.

This connection is important to maintain the voltage stability required by the Arduino UNO and relay module to operate efficiently.

c. Connection with Relay

At this stage, pins A4 and A5 are used to control the relay module. A relay is a component that is responsible for opening or closing a larger electrical circuit based on commands from Arduino. The relay will connect or disconnect the flow of electricity to the device connected to the circuit.

d. Testing Process and Timing

After the entire circuit is properly connected, testing is carried out to verify the performance of the timer system. Arduino UNO will initiate a command to activate or deactivate the relay based on a predetermined time, which is calculated and controlled by the timer in the Arduino programming code. This timer can be adjusted according to user needs, either to count seconds, minutes, or hours to control electrical devices.

e. Measurement and Evaluation

To evaluate the system performance, measurements are made on the accuracy of the timer, the relay response to commands, and the stability of the power flow to the controlled device. The test results will be compared with the programmed time target to ensure the system is functioning properly.

Results and Discussion

1. Electrical control system

This designed electrical control system automates the use of electrical equipment in a room through the integration of timers, relays, and Arduino Uno microcontrollers. The timer functions as an automatic time marker to set the room usage schedule. When the specified time is reached, the buzzer siren sounds as a warning that activity in the room is about to begin. The duration of the siren sound, which can be adjusted to about one minute, provides clear and

effective notification to room users. After the siren duration is over, the system automatically turns on the electricity through a relay controlled by the Arduino Uno. The relay receives a signal from the timer or SMS, then flows electricity to activate equipment such as lights, fans, or other electronic devices.

In addition to using a timer, this system also supports remote control via short message service (SMS). By sending a specific keyword, such as *#9* to turn on the electricity, users can manually control the equipment in the room if needed. The advantages of this system include energy efficiency, automation, and ease of operation, as well as safe electrical control. However, challenges such as technical failures in relays or timers, as well as dependence on SMS signals, require special attention. Periodic testing and the use of alternatives such as internet connection or manual control can be solutions to improve the reliability of this system. Overall, the integration of this system is able to provide efficient, safe, and easy-to-use electrical control.

Figure 5. Keyword Testing Results

Table 1. Tests that have been designed:

Date	Set Timer	Test Scenario	Test Results	Status
July 11, 2024	17:00	Set the time to turn on in Schedule 1	Turns on at the specified time	On time
July 11, 2024	18:00	Set the time to turn on in Schedule 1	Turns on beyond the specified time	Delay 2 minutes
July 12, 2024	13:00	Set the time to turn on in Schedule 1	Turns on at the specified time	On time
July 12, 2024	15:00	Set the time to turn on in Schedule 1	No flame	Error

Source: 2024 data processing

Table 1 shows the test results of the designed timer-based electrical control system. In the test on July 11, 2024 at 17:00 and July 12, 2024 at 13:00, the system successfully turned on the electricity at the specified time, indicating performance in accordance with the design. However, in the test on July 11, 2024 at 18:00, there was a delay of 2 minutes, indicating a delay in system execution. In the last test on July 12, 2024 at 15:00, the system failed to turn on the electricity according to schedule, indicating an error that requires further evaluation of the hardware or software.

Table 2. SMS Testing If Components Are Not Working

Date	Component Status	SMS Information
August 11, 2024	Light 1 On, Light 2 On, Fan On, Computer On	No information

August 2024	11,	Light 1 On, Light 2 On, Fan Off, Computer On	Fan Dead
August 2024	11,	Light 1 Off, Light 2 On, Fan On, Computer On	Lamp 1 Off
August 2024	12,	Light 1 On, Light 2 Off, Fan On, Computer On	Light 2 Off
August 2024	12,	Light 1 Off, Light 2 Off, Fan On, Computer On	Light 1 Off, Light 2 Off
August 2024	12,	Light 1 On, Light 2 On, Fan Off, Computer Off	Computer Dead, Fan Dead

Source: 2024 data processing

Table 2 shows the results of the SMS system test that provides information if a component is not working. In the test on August 11, 2024, when all components were working normally, no SMS was sent. However, if a component is damaged, such as a dead fan or a dead light, the system sends an SMS with the appropriate information, such as "Fan Dead" or "Light 1 Dead". This system is effective in providing notifications to facilitate monitoring of device conditions.

2. Electrical control system test

This electrical control system is designed to ensure efficiency and automation in the use of electrical equipment in the room. After the time specified by the timer is reached, the buzzer siren will sound as a sign that the room usage time will start soon. This siren sound lasts for approximately one minute, with a duration that can be adjusted as needed through system settings. When the siren duration is over, the electric current in the room is automatically activated by a relay controlled by the Arduino Uno microcontroller. This relay is responsible for flowing electricity to various equipment in the room, such as lights, fans, or other electronic devices.

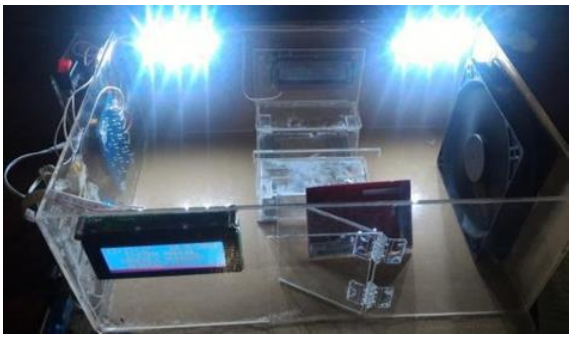

Figure 6. Results of testing the room electrical control device

This automatic mechanism not only provides convenience for users but also increases energy efficiency by ensuring that electrical equipment is only active when needed. In addition, control can be done via SMS, so users have the flexibility to manually turn the electricity on or off if needed. This allows the system to continue to function optimally even if there is a sudden need or a change in schedule. With the integration of timers, buzzers, relays, and Arduino Uno, this system provides a reliable, energy-efficient, and practical solution for managing electricity usage in a room.

Table 3. Electrical Control Testing with Timer and SMS

Date	Time	Activity	Results	Status
August 11, 2024	07:00	The buzzer siren sounds	The siren sounds for 1 minute	Succeed
August 11, 2024	07:01	The electric current is turned on by a relay	Electrical equipment in the room is on	Succeed
August 11, 2024	12:00	Timer goes off, power goes out	Electrical equipment in the room is turned off	Succeed
August 12, 2024	09:00	The buzzer siren sounds	The siren sounds for 45 seconds	Succeed
August 12, 2024	09:01	The electric current is turned on by a relay	Fan and lights on	Succeed
August 12, 2024	13:00	The buzzer siren sounds	The siren sounds for 1 minute	Succeed
August 12, 2024	13:01	The electric current is not on	Relay failed to process	Fail

Source: 2024 data processing

Conclusion

Based on the design and testing results that have been carried out, it can be concluded that the Arduino Uno microcontroller-based electrical control system integrated with a timer has succeeded in creating an effective tool for automatically regulating the flow of electricity in a room. This system is able to control electricity with a high level of time accuracy, thus ensuring that electrical equipment is turned on according to a predetermined schedule. When the set time is reached, the flow of electricity is activated automatically without requiring manual intervention.

In addition, this system is equipped with a remote control feature via SMS that provides notification if there is damage or malfunction in one of the electrical components. This feature increases the reliability and ease of operation of the system, because users can find out the condition of the equipment in real time and take repair steps if necessary. Thus, this tool offers an efficient, practical and safe solution for managing electricity usage in the room.

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