Automatic Lighting System Design Using Sound Sensor

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ABSTRACT
This study aims to design and implement a sound sensor-based lighting automation system that can function during a power outage. This system utilizes a backup energy source from a battery that is distributed through an inverter to ensure smooth operation of the lights even if the main power is cut off. The Arduino microcontroller is programmed to receive input from the FC-04 sound sensor, which detects sound signals as commands to turn the lights on or off. This system uses a relay as an electronic switch controlled by Arduino, which allows the lights to turn on or off based on voice commands. The test results show that the system functions well, with a fast response to sound changes and efficient operation. The test was conducted using three 5-watt lamps, and the response to voice commands can be done well at a distance of 3 meters. The appropriate sound threshold setting and system response speed provide a smooth and efficient user experience. This study shows that a sound sensor-based lighting automation system can be a practical and efficient solution for controlling household lighting, while also providing ease of use in emergency conditions due to power outages.

Keywords: Light Automation, Sound Sensor, Arduino Microcontroller, Inverter, Backup Energy, Relay, Voice Control, Automatic System.

Introduction

The world of technological advancement in the modern era has brought significant changes in various aspects of life, especially in terms of comfort and efficiency. One of the prominent developments is in the field of home automation, where technology not only helps make daily work easier, but also improves people's quality of life. Automatic control systems are increasingly being applied for various purposes, from industry to households. This technology allows devices to operate automatically with little or no human intervention, providing greater comfort and efficiency.

Microcontroller is one of the main components in an automatic control system. A microcontroller is a miniature computer system contained in a chip. Inside it is integrated a processor, memory, and input-output interface that can be programmed as needed. Unlike general-purpose microprocessors that require a minimum system to operate, microcontrollers can work independently in various applications, especially in simple automation. One technology that is starting to be widely applied to microcontrollers is the use of sound sensors, which are able to detect sound waves to activate or deactivate devices.

In the household context, voice control technology provides a practical solution to operate various electrical devices without having to move. This system can be applied to control home lighting, such as turning lights on or off with voice commands. With this technology, lights can be controlled automatically based on voice, providing flexibility and convenience in managing home lighting. In addition, the use of an automatic system based on voice sensors also has the potential to save energy by ensuring that lights are only turned on when needed.

A microcontroller is a miniature computer system on a single chip that functions independently. Inside this chip there is a processor core, a small amount of memory (either RAM or program memory), and input-output devices that can be programmed as needed. Microcontrollers differ from common microprocessors that are usually used in personal computers (PCs), because microcontrollers only require a minimum system to operate. This minimum system is a basic electronic circuit that allows the microcontroller IC to work. Therefore, microcontrollers can be categorized as microcomputers, which integrate CPU, memory, and I/O in one chip.

The term "microcontroller" is often abbreviated as μC, uC, or simply "microcontroller" in everyday discussions. Microcontrollers are generally equipped with GPIO (General Purpose Input Output Pins), which allow these pins to be programmed as needed as inputs or outputs, depending on the desired application. This capability makes microcontrollers very flexible to be applied in various automation applications, including controlling electronic devices at home.

One example of the application of microcontroller technology that is widely used today is a voice-based home lighting control system. By using a sound sensor as input, this technology allows users to turn lights on or off with just a voice command, without having to approach a switch or other control device. The sound sensor detects sound waves in the surrounding environment, which are then translated by the microcontroller as a command to turn the lights on or off.

The design of an automatic lighting system using a sound sensor is expected to be an innovative solution to create a smarter and more efficient home environment. This technology will not only make everyday life easier, but also be a reference for the development of the concept of a future home, where everything can be operated more easily and comfortably. Based on these reasons, the author is interested in conducting research and designing an automatic lighting system based on a sound sensor, which is expected to contribute to the development of home automation technology in the future [9].

Formulation of the problem:

1) How to optimize the sensitivity of the sound sensor to detect changes in sound levels accurately?
2) How to Set the right sound threshold to turn the lights on and off efficiently.?
3) How to Implement fast response to voice changes to provide a seamless user experience.?

LITERATURE REVIEW

1. Microcontroller as the Main Component of Automation System

Microcontrollers are a key component in various automation systems, especially for applications that require simple yet effective control. According to Brown (2019), microcontrollers offer a more affordable and efficient solution than general microprocessors because they combine processors, memory, and input-output components in a single compact chip. In a study conducted by Khan and Patel (2018), microcontrollers showed advantages in terms of cost and power efficiency, especially in applications that do not require high computing power such as controlling lights and other household devices.

Microcontrollers are often used in home automation systems because of their ability to operate with low power consumption and their flexibility to be integrated with sensors, including sound sensors. This makes it easy for developers to design systems that can automatically control home appliances based on certain inputs, such as sound or movement.

2. **Sound Sensor as Input in Automation System**

A sound sensor is a device that can detect sound waves in its surroundings and convert them into signals that can be processed by a microcontroller. Research by Lee and Park (2021) highlights how sound sensors can be integrated into automation systems for smart homes, allowing control of electronic devices using only voice. The system uses a simple speech recognition algorithm that can be implemented on a microcontroller to process voice input and control devices as per commands.

The use of voice sensors in home automation also contributes to energy efficiency. Johnson (2023) asserts that voice-based control allows devices to be activated only when needed, which helps reduce unnecessary energy consumption. In addition, this technology provides easy accessibility for users with physical disabilities, who may have difficulty accessing conventional switches.

3. Home Automation Applications with Microcontrollers

The use of microcontrollers in home automation is growing with the increasing need for convenience and efficiency. Microcontrollers enable accurate and responsive control of a variety of household devices, including lighting, security systems, and other electronic devices. Brown (2019) shows that microcontrollers can be easily programmed for a variety of functions, including adjusting lighting based on environmental conditions or user voice commands [6].

Recent research has emphasized the importance of the minimum system requirements for microcontroller operation. By utilizing basic electronic circuits, microcontrollers can be integrated with various sensors, such as sound sensors, to create a smart home environment that can respond to the needs of its occupants automatically (Khan & Patel, 2018).

Johnson (2023) notes that security is also a major concern in voice-based systems, due to the potential for unwanted or unauthorized voice commands to trigger a response from an automated device. In this context, the use of more sophisticated voice recognition algorithms can improve the reliability and security of the system.

4. Future Trends in Home Automation

The trend of home automation development continues to show an increase, especially in the use of voice sensors and microcontrollers. Johnson (2023) predicts that further integration between sensors, artificial intelligence, and microcontrollers will enable smarter and more adaptive smart homes. This system is expected to be able to recognize user habits and automatically adjust devices according to daily needs. In addition, the development of more powerful and energy-efficient microcontroller technology will further encourage the adoption of automation systems in the future.

Research Method

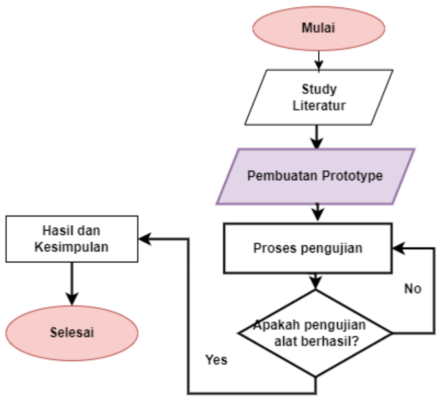

Figure 1. Flowchart

The following is a flowchart description:

1) Start: The starting point of the process.
2) Literature Study: Conducting research and reviewing relevant literature to understand theoretical background or gather information.
3) Prototyping: This stage involves wiring the components, programming the microcontroller to respond to input from the sound sensor, and initial testing to ensure all components are working properly.
4) Process: Testing or analyzing prototypes through experiments or practical applications.
5) Was the Tool Testing Successful?
6) Decision point: If "Yes", proceed to Results and Conclusions.
7) If "No", go back to "Prototyping" to refine the design or approach.
8) Results and Conclusions: Based on successful testing, analyze the data and summarize the results.
9) Done: The process ends here.

Results and Discussion

1) Optimizes the sensitivity of the sound sensor to accurately detect changes in sound levels.

The lighting automation system designed in this study aims to provide a lighting solution that can operate automatically, even when there is a power outage from the main source, namely PLN. This system utilizes backup energy from the AKI as an alternative source of power when the power goes out. The main components used include the AKI, inverter, Arduino microcontroller, sound sensor, and relay. The combination of these devices allows the lights to be controlled via voice commands, without the need for physical switches.

Under normal conditions, the lights operate using power from PLN. However, if there is a power outage, the system automatically switches to backup energy provided by the AKI. This AKI is connected to an inverter, which is responsible for converting the direct voltage from the AKI to 220V AC voltage, according to the needs of household appliances. At the same time, the Arduino will be in standby mode, ready to receive instructions from the sound sensor.

This sound sensor acts as the main input in the system, where the sensor has been programmed to detect a specific sound code that is used to control the lights. When the right sound instruction is detected, the Arduino sets the relay to switch from Normally Open (NO) to Normally Closed (NC), so that the lights turn on. Conversely, to turn off the lights, another sound instruction will return the relay to the Normally Open position, which causes the lights to go out.

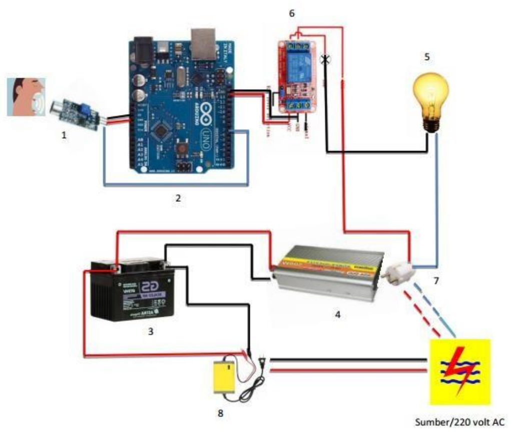

Figure 2. System mechanism on the tool

The system operates through several key steps. When a power outage occurs, the inverter immediately activates the power supply from the battery, ensuring that the entire circuit continues to run. When the sound sensor receives a command to turn on the lights, the Arduino changes the relay position from NO to NC. Likewise, when there is a sound instruction to turn off the lights, the relay returns to the NO position.

This automation system offers several key advantages, including ease of lighting operation without the need for manual switches, energy efficiency through the use of battery backup, and the convenience of controlling devices with just voice instructions. This not only increases user convenience, but also allows for the implementation of a smart home concept that is more efficient and responsive to everyday needs. To optimize the sensitivity of the sound sensor to accurately detect changes in sound levels, there are several steps that can be taken. First, choosing the right sound sensor is very important, such as an electret or MEMS microphone that is sensitive to sound and can respond quickly. Furthermore, the use of a signal amplifier can improve the quality of the signal received from the sensor, ensuring that weak sounds remain clear.

Threshold settings are also needed to distinguish between relevant sounds and background noise, so that the system only responds to desired sounds. In addition, digital filters can be applied to filter out irrelevant sounds, so that only certain sounds are recognized. Periodic calibration helps *the* system adjust its sensitivity to environmental conditions.

2) Set the right sound threshold to turn the lights on and off efficiently.

The overall system testing using lights as indicators focuses on how the lighting automation system can work well when there is a power outage, using the FC-04 sound sensor as input and the Arduino Uno R3 as a controller. This test aims to ensure that the lights can be controlled automatically through voice instructions, by turning the lights on or off according to the sound code received by the sound sensor.

In this test, the lamps used have a power of 5 watts each, which serves as an indicator that the system is working properly. When a power outage occurs, the system switches to the power backup provided by the AKI and inverter, ensuring that the Arduino and other components continue to operate. The FC-04 sound sensor works by detecting sound waves received by the microphone, which then produces a signal that is processed by the LM393 chip. This signal is in the form of an output of 1 and 0, which is then forwarded to the Arduino microcontroller (ATmega 328 chip), which has been pre-programmed to process sound signals based on a certain duration, namely 500 ms for sound signal validation.

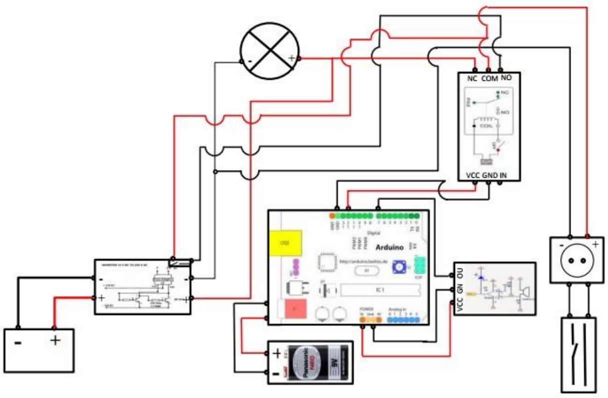

Figure 3. System and control on the tool

The Arduino that receives this signal then controls the 5V DC relay, which functions as an automatic switch. The working principle of this relay uses two main terminals: the COM and NC (Normally Closed) terminals that are connected when the relay is not energized, and the COM and NO (Normally Open) terminals that are connected when the relay is activated by the voltage from the Arduino output pin 13. When the Arduino detects valid sound input (such as clapping or other sounds), the output pin 13 produces a 5V voltage which then flows to the VCC on the relay, changes the contact position from NC to NO, and turns on the light connected to the NO terminal of the relay.

Thus, this system allows users to control the lights simply by giving voice instructions, providing convenience in operating electrical appliances at home, especially in emergency situations such as power outages. This test shows that the system can function well, provide a quick response to voice and is reliable in conditions of power outages from PLN.

Setting the right sound threshold is essential to ensure that the lighting automation system can turn the lights on and off efficiently. The sound threshold refers to the level of sound intensity received by the sound sensor that the system can interpret as a command to control the lights. If the threshold is too low, the sensor may respond to irrelevant sounds, such as background noise, causing the lights to turn on or off inadvertently. Conversely, if the threshold is too high, the sensor may not respond to the intended sounds, such as clapping or other voice commands. Therefore, setting the right sound threshold involves adjusting the sensor sensitivity to ensure that only valid sounds, such as commands from the user, can turn the lights on or off, while ignoring unwanted sounds. This process is crucial to improving the reliability and usability of the system.

3) Implement quick response to voice changes to provide a seamless user experience.

Table 1. which contains a test of the lighting control system with a distance of 3 meters:

No	Initial Condition of the Lamp	Sound Input	Sound Sensor Value	Sound Sensor Output Voltage	Final Condition of the Lamp
1	Blackout	1 clap	> 400 ms	0.5 V	Light up
2	Blackout	1 clap	< 400 ms	0.5 V	Blackout
3	Light up	1 clap	> 400 ms	0 V	Blackout
4	Light up	1 clap	< 400 ms	0 V	Light up

Table 1 shows the test results of the lighting control system using a sound sensor at a distance of 3 meters. In this table, the initial conditions of the lights and sound input in the form of clapping are analyzed to see how the sound sensor responds and changes the condition of the lights based on the sound sensor value received. In the first test, the lights were off and the sound sensor received one clap with a duration of more than 400 ms. The sound sensor value received was more than 400 ms, which produced an output voltage of 0.5 V, indicating that the lights were successfully turned on. The final condition indicates that the lights were on, according to the instructions given by the sound. In the second test, although sound input in the form of clapping was also given, the duration received was less than 400 ms. Although the sound sensor received a value lower than the threshold, the output voltage remained at 0.5 V, which caused the lights to remain off. This shows that the system can distinguish differences in sound duration and only responds to sounds with a duration that matches the system settings.

In the third trial, the lamp is on and the sound sensor receives a single clap with a duration of more than 400 ms. The result is a sound sensor value greater than 400 ms, and the output voltage is 0, which causes the lamp to go out. This indicates that the system can turn off the lamp when the corresponding voice command is given, even though the lamp is initially on. In the fourth trial, the initial condition of the lamp is on and the sound sensor receives a clap with a duration of less than 400 ms. The output voltage remains 0, which means the lamp remains on. This result indicates that only a duration longer than the threshold can trigger a change in the lamp state, emphasizing the importance of proper threshold setting to ensure accurate and responsive control. This trial shows that the sound sensor system can control the lamp state well based on the duration of the clap, with efficient threshold setting to minimize detection errors and ensure the lamp functions according to the voice command given.

Conclusion

study shows that the designed sound sensor-based lighting automation system can function well to control lights automatically, especially during a power outage. This system utilizes backup energy from the battery which is distributed through an inverter to ensure smooth operation even if the main power source is cut off. The Arduino microcontroller, which is programmed to respond to signals from the sound sensor, can control the relay to turn the lights on or off based on voice commands.

The test results show that the system works according to the programmed instructions, with a fast response to sound changes and smooth operation. The precise sound threshold setting and efficient programming on the Arduino allow the system to respond accurately to voice commands, both in quiet and noisy rooms.

Overall, this system offers the advantage of ease in controlling lights with just your voice, without the need for a physical switch. In addition, the use of AKI as an energy reserve makes this system efficient in utilizing existing resources and continues to function when there is a disruption in the electricity supply from PLN. Thus, this system can be a practical and efficient solution for household lighting automation.

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