DOI: 10.35598/mcfpga.2026.011

Development of an Arduino Uno-Based Smart Lighting Control System Using Ambient Light and Motion Sensors

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***Abstract*—The paper considers the development of an intelligent lighting control system based on the Arduino Uno microcontroller using light and motion sensors. The proposed approach provides automatic adjustment of lighting parameters in accordance with external conditions and the presence of users in the room. The system was modeled in the Tinkercad virtual environment. The results of the study indicate the possibility of reducing unproductive electricity consumption and increasing the efficiency of using a light-emitting diode light sources.**

Keywords—Arduino Uno, smart lighting, light sensor, motion sensor, energy efficiency, Tinkercad.

I. Introduction

Increasing the efficiency of energy resources is one of the priority areas of development of modern energy. According to experts, a significant share of electrical energy in administrative, educational and residential buildings is spent on lighting needs. At the same time, traditional lighting systems do not take into account changes in external conditions and the actual presence of people in the room, which leads to overconsumption of electricity.

Intelligent lighting control systems allow you to automatically adapt the parameters of the luminaires to the current operating conditions. The use of microcontroller platforms opens up opportunities for creating inexpensive and effective solutions suitable for integration into the concept of smart buildings and the Internet of Things.

One of the key requirements for modern energy monitoring and management systems is to ensure their accessibility, ease of operation and modular structure, which allows for the phased implementation of functional components in accordance with user needs and available technical capabilities [1].

The active development of Internet of Things technologies contributes to the widespread implementation of wireless energy resource monitoring and management systems that provide remote access to energy consumption parameters and their operational regulation using mobile devices [2]. The use of such an approach allows users to perform centralized power consumption management without the need for direct access to elements of the electrical infrastructure, in particular electrical panels, electricity metering devices and switching equipment [3].

The proposed system can function as an autonomous solution, but its architecture provides for the possibility of integration into complex intelligent building management systems. This creates conditions for automated execution of control actions without direct user participation, while maintaining the ability to constantly monitor energy consumption parameters and promptly obtain information about the system status [4].

The purpose of the work is to develop and study an intelligent lighting control system based on Arduino Uno using light and motion sensors.

II. Research Methods And Equipment

To implement an intelligent lighting control system, the Arduino Uno platform based on the ATmega328P microcontroller was used. The choice of this platform is due to its accessibility, widespread use, ease of programming and the possibility of integration with various sensor modules.

The following research methods were used in the work:

- analysis of modern automated lighting control systems;
- methods of computer modeling of electronic circuits;
- experimental study of the system in a virtual environment;
- comparative analysis of the operating modes of the lighting installation;
- assessment of the energy efficiency of the developed control algorithm.

The developed system includes:

- "Arduino Uno" microcontroller;
- photoresistor (illumination sensor);
- infrared motion sensor PIR;
- LED lamp;
- PWM brightness control module;
- power and switching elements.

Modeling and testing of the system's performance were performed in the Tinkercad environment, which allows you to create electronic circuits, program Arduino microcontrollers in C and study the behavior of the system in different operating modes without using physical equipment.

The system's operating algorithm is based on the analysis of two main parameters: the level of natural light and the presence of a person in the control zone. The received data is processed by the microcontroller, after which a control signal for the LED lamp is formed. Thanks to the use of pulse-width modulation, smooth brightness control is ensured depending on environmental conditions.

Modern lighting design involves the integration of digital technologies and automation tools that provide flexible control of the parameters of the lighting environment. According to the provisions highlighted in the article [5], the improvement of lighting quality is achieved by combining energy-efficient light sources with intelligent control systems capable of adapting operating modes to the needs of users and the characteristics of the room.

III. Results And Discussion

In the process of modeling, the functioning of the system under different operating conditions was investigated. It has been established that the use of a light sensor ensures the maintenance of the necessary level of light flow in accordance with the change in natural light.

The use of a motion sensor makes it possible to avoid the operation of the lighting installation in the absence of people in the room. This is especially relevant for corridors, classrooms, offices and auxiliary premises, where a large part of electricity is wasted.

The simulation results showed that the use of an adaptive control algorithm makes it possible to reduce the energy consumption of the lighting system without worsening the conditions of visual comfort. In addition, reducing the duration of operation of LED light sources helps to increase their service life and reduce maintenance costs.

The proposed solution can be used as a separate automation module or as a component of complex management systems of engineering networks of buildings.

An intelligent lighting control system based on the Arduino Uno microcontroller using light and motion sensors has been developed. The simulation results confirmed the effectiveness of the proposed approach in reducing unproductive electricity consumption.

Further research should be directed towards expanding the functionality of the system by using wireless data transmission technologies and integration with Internet of Things platforms. The results obtained confirm the feasibility of taking into account the color characteristics of LED light sources when designing intelligent lighting control systems, which ensures a combination of energy efficiency, high quality of the lighting environment, and the principles of human-centered lighting [6].

Acknowledgment

The authors express their sincere gratitude to the staff of the Department of Lighting Engineering and Light Sources of the O.M. Beketov NUUEKh, as well as to O. G. Litvinov for the consultations provided, valuable scientific and methodological materials, and support during the research.

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