AUTOMATION AND COMPUTER-INTEGRATED TECHNOLOGIES

UDC 628.972(045)
DOI:10.18372/1990-5548.63.14519

[1]M. P. Vasylenko,
[2]I. Yu. Saponiuk

AUTOMATIC SYSTEM OF LIGHTING CONTROL IN RESIDENTIAL BUILDINGS

[1,2]Aviation Computer-Integrated Complexes Department, National Aviation University, Kyiv, Ukraine
E-mails: [1]m.p.vasylenko@nau.edu.ua ORCID 0000-0003-4937-8082, [2]irasaponyuk@gmail.com

***Abstract*—*This work is devoted to the automation of residential buildings lighting systems. Analysis of existing lighting systems was held to find the ways of further improvement. A structure of proposed system was developed. All the elements of the experimental installation, including drivers, photosensors, lighting fixtures, microcontroller, were chosen. Algorithm of system operation was created and software for microcontroller was designed. Proposed algorithm allows to take into account the reflective properties of interior elements and to provide the higher quality of lighting.*

Index Terms—Microcontroller; automatization; photosensors; illumination; automatic brightness control.

I. INTRODUCTION

Nowadays the producing of electricity is accompanied by pollution the magnitude of which could be threatening to the environment in the future. That's why at the moment energy saving is one of the most important tasks. This is connected with the scarcity of main energy sources, the rising cost of their production, and global environmental concerns.

Energy conservation is essential in any field of human life. The analysis of losses in the sphere of production, distribution and consumption of electricity shows that most of the losses - up to 90 percent – are in the sphere of energy consumption, while losses in the transmission of electricity make only 9–10%.

Therefore, the main energy saving efforts are concentrated in the area of electricity consumption. At present, the main tendency and important pattern of development of light sources is their further improvement, including improvement of economy, reliability, efficiency, safety, quality of color transmission. Even today, economically advantageous fiber-optic lighting is being actively implemented, controlled combined lighting and transmission systems are being created indoors, and remote control of lamps [1].

There are ways to use electricity, it's "smart" lighting systems that have been known for long. The energy-saving effect is based on the fact that the light turns on automatically when it is needed. Such lighting systems use energy-saving lamps. Among the environmental factors affecting the human body in the process of work, light is one of the leading places.

There are ways to use electricity, it's "smart" lighting systems that have been known for long. The energy-saving effect is based on the fact that the light turns on automatically when it is needed. Such lighting systems use energy-saving lamps. Among the environmental factors affecting the human body in the process of work, light is one of the leading places.

It is known that almost 90 percent of all environmental information is obtained through the organs of vision. The ability of a person to navigate in space, to carry out physiological functions, to perform different types of work depends on the type and quality of lighting in the environment. Thus, the safety of human life is affected by lighting conditions. Based on all of the above, hygienic rational lighting both at work and at home is of great positive importance. Optimal light conditions affect human activity and performance. When it comes to lighting, it is also important to pay attention to saving electricity.

II. ANALYSIS OF EXISTING SYSTEMS

The problems of ecology in the modern world, the economic crisis and, at the same time, the rapid development of IT technologies are forcing developers and homeowners to pay more attention to the issues of energy efficiency and energy independence of residential objects. But no less important nowadays in the construction industry is the introduction of "smart technologies" capable of effectively managing the home.

In Western countries, the number of commissioned SMART facilities is increasing. SMART-technology provides a control and automation system, which is a complex of high-tech devices designed to automate the processes and operations that occur during the operation of life support systems of residential objects [2]. Despite the variety of data technologies used in "smart homes", the composition of the systems and the scheme of operation are not fundamentally different. Components of any system:

- system access point (controller, processor);
- actuators;
- controls;
- information transmission lines.

An automated lighting system is a computerized network capable of responding to a variety of external events and changing the operation of devices connected to it, as well as a smart home (Fig. 1). The latter are groups of wall or table lamps, emergency lamps or garden lights – that is, any lighting device.

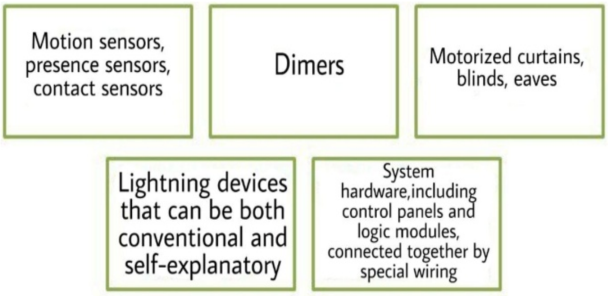

Fig. 1. Elements that control the illumination with intellectual qualities

Any control of the smart home system is suitable for lighting control. Three actuators are used as an actuator – relays, dimers, and DMX controllers. Prior to the appearance of all these devices, the only way to reduce or increase the intensity of illumination was to reduce or increase the number of light bulbs of a certain power. Additional lighting control devices are motion sensors, the principle of which is based on infrared radiation.

However, such sensors will not be effective if the person is immobile – the lack of movement for them means the need to turn off the lights. In this case, special devices are suitable – presence sensors that activate lighting throughout the time while one of the households is in the room and turn off the light when there are no people in the area of their sensors.

Presence sensors are much more sensitive than motion sensors; they include illumination in any, even weak, movement within their range. In addition to the described lighting controls, there are wiring accessories with timers and circuit breakers. The first type is designed to supply electricity for a certain amount of time, which is convenient, for example, when controlling lighting devices on stairwells.

Products of the second type – sockets, automatically disconnect the power supply during network congestion, short circuit and leakage of current outside the mains (into the ground). Timers are devices that supply electricity for a certain period of time.

They can be used not only for the elementary inclusion of light bulbs, but also to regulate the operation of various devices, such as illumination in the aquarium. Light management in a smart home has great functionality. One of them is to control the lighting from the remote control unit.

Another way to control light in the home is to program template light scenarios.

III. Problem Statement

According to SBD B.2.5-28-2006 [3], a room with permanent residence should normally have natural light.

Without natural lighting, it is allowed to design rooms that are defined by state building standards for the design of buildings and structures, regulatory documents for the construction design of buildings and structures of certain industries approved in the prescribed manner, as well as premises, the placement of which is allowed in the basement floors of buildings.

For general artificial light, indoor light sources should be used as a rule, preferring the same power to the light sources with the highest light output and service life.

Natural lighting is divided into lateral, upper and combined (upper and lateral).

The statutory value of natural light coefficient (NLC), for houses located in different areas, should be determined by the formula:

$$e_N = e_n \cdot m_N, \tag{1}$$

where e_n is the value m_N of the NLC by the State Building Normes [3]; is the coefficient of light climate by the Table 3.2 of State Building Normes [3]; e_N is the number of the natural light supply group by the State Building Normes [3].

Combined lighting of residential, public and ancillary buildings is allowed to be provided when it is necessary to make rational space-planning decisions except for living rooms and kitchens of residential and dormitories, living rooms and rooms of hotels, dormitories and bedrooms recreation, group and gaming children's preschools, chambers of medical and preventive institutions.

For general room lighting, the most economical discharge lamps with a light output of at least 55 lm/W should be used.

The choice of light sources by color characteristics should be made on the basis of Appendix G of State Building Normes [3].

The luminous output of light sources for artificial illumination of premises at minimum acceptable color rendering indices shall not be less than the values are also specified in State Building Normes [3].

Artificial lighting is divided into working, emergency, security and duty. Emergency lighting is divided into safety lighting and evacuation. As a general rule, indoor light sources should be used for general artificial lighting, giving preference to one light source with the highest light output and lifetime.

On average, the costs of providing a two-room apartment will be approximately € 3,500, a three-room apartment will cost € 5,000, and an average-sized two-storey cottage will cost € 8,000. This system is a step into the future for humanity, because it saves energy, streamlines it and, in addition, allows the user to simplify his life and make it more comfortable.

The owner of such a system in his home offers many opportunities to adjust the lighting according to their wishes and needs.

However, there are also disadvantages to the system, because its installation and development are very expensive and not every average resident can afford this luxury [4].

The automated lighting system thus developed must meet all of the listed sanitary and hygienic requirements for residential lighting and be substantially less expensive than analogues available on the market.

Development of such system requires to solve the following tasks:

1. Design the structure of the system.
2. Perform the selection of components for every block of the structure.
3. Design the algorithm of system operation.
4. Design the software for the system.

IV. PROBLEM SOLUTION

Structural diagram of the developed system is shown in Fig. 2.

Manual control is used to switch between the systems operation modes and allows to adjust brightness for each lighting fixture in manual operation mode and for starting the calibration mode. It also provides indication of system operation modes and errors.

An ATmega328 / P microcontroller was used as the CPU in the designed system. The ATMega328 microcontroller is an 8-bit low power CMOS microcontroller based on an advanced AVR RISC architecture.

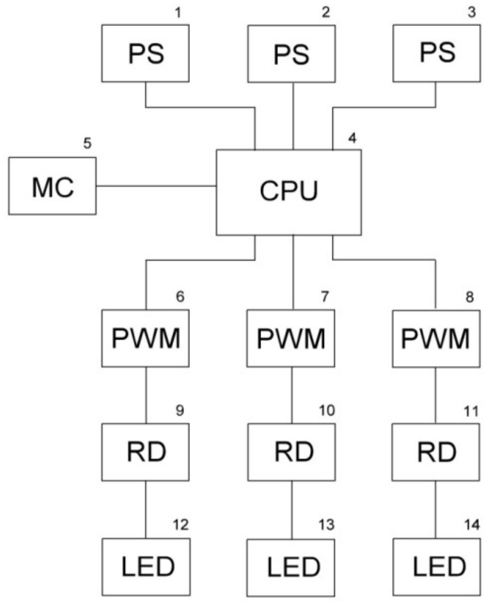

Fig. 2. Structure diagram of layout of automated lighting control system: 1, 2, 3 are photosensors; 4 is the microcontroller; 5 is the manual remote control; 6, 7, 8 are pulse width modulators, 9, 10, 11 are remotely controlled drivers, 12, 13, 14 are LED light fixtures

The memory consists of programmable memory (32 KB), RAM (2 KB) and EEPROM (1 KB) permanent memory. Peripherals include: two 9-bit timer / counter with module and frequency divider, 16-bit timer / counter with module and frequency divider, as well as recording mode, real-time counter with separate generator, six PWM channels, 6-channel DAC with built-in temperature sensor, USART software serial port, SPI serial interface, I2C interface, software watchdog timer with separate internal generator, internal voltage comparison circuit and processing unit and wake-up when changing voltages at the outputs of the microcontroller.

A remotely controlled driver was selected to connect the diode light, since microcontroller itself cannot supply necessary power to the lighting fixture. AP1694 driver was selected for designed system because of its features. It provides primary side control for output current regulation without opto-coupler, wide range of dimmer compatibility, dimming curve compliant with NEMA SSL6 standard, etc. Schematic of AP169r driver is shown in Fig. 3.

The AP1694 is an AC-DC controller that provides a universal high-performance driver solution for a variety of mains-dimmable LED lamp designs. It's suitable for both 120 V and 230 V AC inputs and supports non-isolated buck, buck-boost and isolated flyback topologies.

The GL55 series photoresistors were used as the primary sensing elements. Features of this type of photo resistor include the fact that it is coated with epoxy resin, fairly reliable, it has high sensitivity, fast response, small volume and a wide operation range. Typical applications of this photoresistor include automatic photometry, camera, photoelectric control, internal signal irradiation control, industrial control, light controller, light control lamp, etc.

Schematic representation of the GL55 series photoresistor is shown in Fig. 4.

Schematic of lighting fixture is shown in Fig. 5.

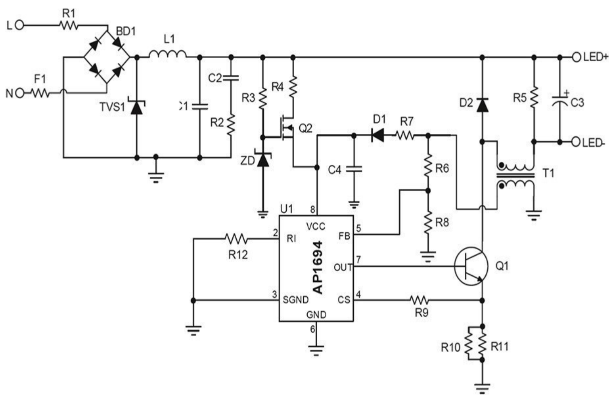

Fig. 3. The schematic of the AP1694 driver

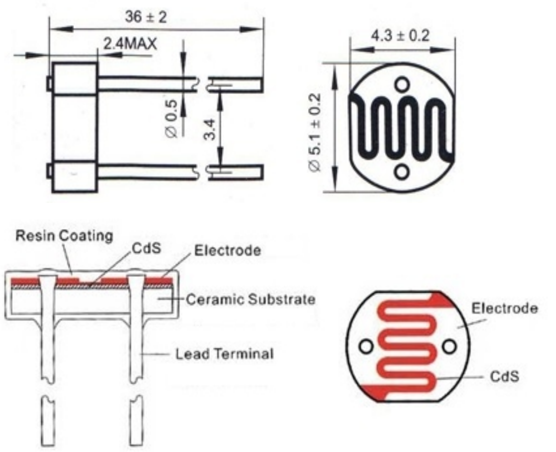

Fig. 4. Schematic representation of the GL55 series photoresistor

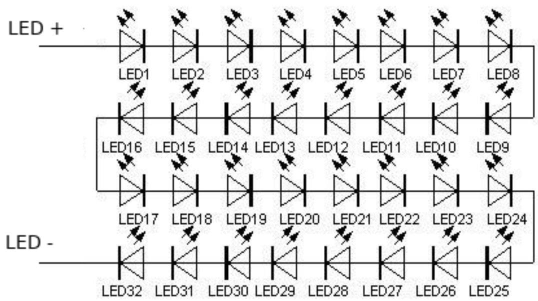

Fig. 5. Lighting fixture schematic

Lighting fixtures are the matrices of light emission diodes that provide necessary brightness of light.

Proposed system allows to provide uniform lighting brightness at required level throughout the depth of the room. Positioning of lighting fixtures can be chosen depending on the size and shape of the room.

Proposed variant of system includes 3 lighting fixtures with maximum luminous flux equal to 850 lux so it can be used to illuminate the room with 20 m^2 area. In this case lamps can be placed as shown in Fig. 6.

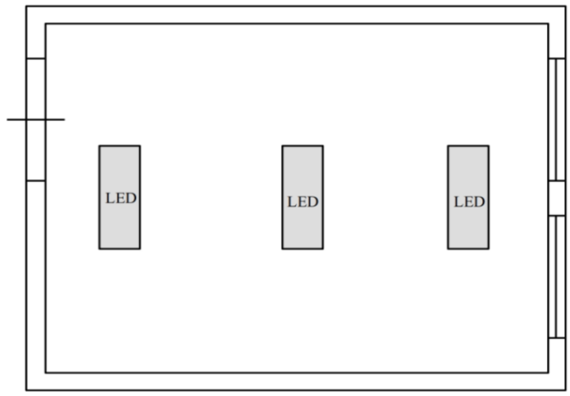

Fig. 6. Positioning of lamps in the room

Brightness if each lamp can be adjusted independently that allows to achieve the same light brightness level throughout the depth of the room. Manual control panel can be placed instead of traditional light switch.

Lighting sensors of the system measure the light reflected from the surfaces (as shown in Fig. 7) so it is necessary to take into account the reflective properties of the actual surfaces such as furniture and other interior elements.

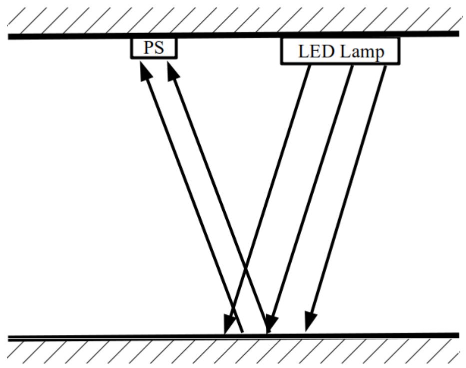

Fig. 7. Example of light sensor positioning

It can be done during the calibration process that can be activated during system initial setup. In this mode controller puts all the light sources to the maximum brightness and measures the values on each photosensors. Than controller calculates the calibration coeffitients and stores them into the

EEPROM. Calibration procedure can be started manually to obtain the new coefficients in case when furniture or some interior elements were changed.

It is necessary to perform calibration with closed curtains to avoid influence of external light that is necessary to provide the normal system operation at the night time.

System can operate in automatic and manual modes. In both modes light turns on and off manually.

In automatic operation mode system measures lighting values for each channel and adjusts brightness of corresponding lamp to obtain the necessary lighting level. This mode has two sub-modes. Primary sub-mode has prescribed brightness level taken from normative documents and preprogrammed into system controllers software. In secondary sub-mode prescribed brightness level can be set manually and system will try to maintain it automatically.

In manual operation mode system turns off the photosensors and brightness of lamps must be adjusted from the control panel. It also has to sub-modes in which brightness can be set for all lamps at the same time or for each lamp separately.

System also has self-test procedures for light sensors and lamps. In case of sensor malfunction it displays the error message on the control panel LCD display and uses the information from neighbouring sensors for the channel with malfunction.

In case of driver malfunction system displays error message and shuts down the corresponding lamp in order to prevent short circuit.

V. Experimental Results

Experimental testing of the designed system was carried out by modelling the external light with manually dimmable light source and measuring the output luminous flux from the system using Testo 540 luxmeter. System wast set to maintain 500 lux on the surface. Measurement area was shielded from the modelled light. Experimental results are shown in Table I.

Experimental results show that deviation from prescribed light levels does not exceed 4 lux. Lighting values, higher than 500 lux were modeled to test if the system will properly operate in case when natural light creates much higher luminous fluxes than prescribed value. Results show that system operates properly and just turns off the controlled light sources.

TABLE I. EXPERIMENTAL RESULTS

Modelled luminous flux, lux	**Output luminous flux, lux**	**Total luminous flux on surface, lux**	**Deviation from prescribed value, lux**
0	504	504	4
50	452	503	2
100	403	504	4
150	354	504	4
200	303	503	3
250	252	502	2
300	202	502	2
350	152	502	2
400	102	502	2
450	51	501	1
500	0	501	1
550	0	552	52
600	0	603	103

VI. Conclusion

Designed system allows to adjust light brightness to necessary levels in automatic or manual modes that in combination with energy saving LED lighting fixtures allows to reduce the household energy consumption for lighting needs.

Use of microcontroller and independent photodensors for each lighting fixture allows to provide the uniform illumination brightness lewel at the full area of room where the system is used. It also allows to avoid situations when the artificial illumination is too bright or too dim.

Used components allows to achieve significant decrease in system costs that makes it affordable for most households.

References

[1] M. E. Soper, *Practical advices and solutions for creating SMART HOUSE*, Moscow: NT.Press, 2007, pp. 432–433. https://doi.org/10.1016/B978-032304195-9.50078-X

[2] T. R. Alsenpeter and J. Welt, *Building the Smart House by ourselves*. Kudits-Obraz. 2005, p. 384.

[3] Natural and artificial lighting: State Building Norms, vol. 2.5–28, 2018.

[4] The perspective of Smart House System's Market Available at: https://www.vira.ru/exp/reviews/umdom.html/ (accessed 5th of October 2019).

Received December 25, 2019

Vasylenko Mykola. orcid.org/0000-0003-4937-8082
Candidate of Science (Engineering). Senior lecturer.
Aviation Computer-Integrated Complexes Department, National Aviation University, Kyiv, Ukraine.
Education: Kyiv National University of Technologies and Design, Kyiv, Ukraine, (2012).
Research interests: renewable energy sources, thermal noise based estimation of materials properties.
Publications: more than 20 papers.
E-mail: m.p.vasylenko@nau.edu.ua

Saponiuk Iryna. Student.
Aviation Computer-Integrated Complexes Department, National Aviation University, Kyiv, Ukraine.
Publications: 1
E-mail: irasaponyuk@gmail.com

М. П. Василенко. І. Ю. Сапонюк. Автоматизована система освітлення в житлових приміщеннях

Роботу присвячено автоматизації систем освітлення житлових будинків. Проведено аналіз існуючих систем освітлення з метою пошуку шляхів їх подальшого вдосконалення. Розроблено структуру запропонованої системи. Були обрані всі елементи експериментальної установки, включаючи драйвери, фотосенсори, освітлювальні прилади, мікроконтролер. Створено алгоритм роботи системи та розроблено програмне забезпечення для мікроконтролера. Запропонований алгоритм дозволяє враховувати світловідбиваючі властивості елементів інтер'єру та забезпечувати більш високу якість освітлення.

Ключові слова: мікроконтролер; автоматизація; фотосенсори; освітлення; резистивні драйвери; державні будівельні норми.

Василенко Микола Павлович. orcid.org/0000-0003-4937-8082
Кандидат технічних наук. Старший викладач.
Кафедра авіаційних комп'ютерно-інтегрованих комплексів, Національний авіаційний університет, Київ, Україна.
Освіта: Київський національний університет технологій та дизайну, Київ, Україна, (2012).
Напрям наукової діяльності: відновлювальні джерела енергії, оцінка властивостей речовин та матеріалів за власними електромагнітними випромінюваннями.
Кількість публікацій: більше 20 наукових робіт.
E-mail: m.p.vasylenko@nau.edu.ua

Сапонюк Ірина Юріївна. Студентка.
Кафедра авіаційних комп'ютерно-інтегрованих комплексів, Національний авіаційний університет, Київ, Україна.
Кількість публікацій: 1.
E-mail: irasaponyuk@mail.ru

М. П. Василенко. И. Ю. Сапонюк. Автоматизированная система освещения в жилых помещениях

Работа посвящена автоматизации систем освещения жилых домов. Был проведен анализ существующих систем освещения с целью поиска путей их дальнейшего совершенствования. Была разработана структура предложенной системы. Были выбраны все элементы экспериментальной установки, включая драйверы, фотосенсоры, осветительные приборы, микроконтроллер. Создан алгоритм работы системы и разработано программное обеспечение для микроконтроллера. Предложенный алгоритм позволяет учитывать светоотражающие свойства элементов интерьера и обеспечивать более высокое качество освещения.

Ключевые слова: микроконтроллер; автоматизация; фотосенсоры; освещение; резистивные драйверы; государственные строительные нормы.

Василенко Николай Павлович. orcid.org/0000-0003-4937-8082
Кандидат технических наук. Старший преподаватель.
Кафедра авиационных компьютерно-интегрированных комплексов, Национальный авиационный университет, Киев, Украина.
Образование: Киевский национальный университет технологий и дизайна, Киев, Украина, (2012).
Направления научной деятельности: возобновляемые источники энергии, оценка свойств веществ и материалов по их собственным электромагнитным излучениям.
Количество публикаций: больше 20 научных робот.
E-mail: m.p.vasylenko@nau.edu.ua

Сапонюк Ирина Юрьевна. Студентка.
Кафедра авиационных компьютерно-интегрированных комплексов, Национальный авиационный университет, Киев, Украина.
Количество публикаций: 1.
E-mail: irasaponyuk@mail.ru