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AUTOMATIC SYSTEM OF ARTIFICIAL LIGHTING CONTROLLED BY COLOR TEMPERATURE

Artificial lighting is one of the largest consumers of electricity, and at the same time the most promising method to save energy, thanks to the emergence and development of more efficient light sources. Insufficient illumination gives rise to "inhibited" state and deceleration of human response. This leads to the need not only to monitor the compliance with the required level of illumination, but also carefully select the type of light source and its color temperature, depending on the type of work, and time of day in which it is performed. A system is developed which allows reproducing the most important parameters of natural lighting - color temperature and level of illumination, according to their natural fluctuations, and decreases power consumption for artificial lighting. This makes it possible to create a complete model of natural light atmosphere that positively affects productivity of work, and physical and mental activity of man.
***Keywords**: RGB light-emitting diode (LED), illumination, color temperature, automatic system.*
Fig. 5. Tab. 2. Lit. 4.

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АВТОМАТИЧНА СИСТЕМА ШТУЧНОГО ОСВІТЛЕННЯ З КЕРУВАННЯМ ЗА КОЛІРНОЮ ТЕМПЕРАТУРОЮ

Штучне освітлення є одним з найбільших споживачів електроенергії, і в той же час найперспективнішим способом економії енергоресурсів, завдяки появі і розвитку більш економічних джерел світла. Недостатня освітленість спричиняє виникнення «загальмованого» стану та сповільнення реакції людини. Це призводить до необхідності не тільки слідкувати, за дотриманням нормативного рівня освітленості, але і ретельно підбирати тип джерела світла і його колірну температуру, в залежності від виду робіт, та часу доби в який вони виконуються. Розроблено систему, що дозволяє відтворювати найважливіші параметри природного освітлення – колірну температуру та рівень освітленості, у відповідності з їх природнім коливаннями та забезпечує зменшення витрат електроенергії на штучне освітлення. Це дає можливість створення повної моделі природної світлової атмосфери, яка позитивно впливає на продуктивність праці, фізичну та розумову активність людини.
***Ключові слова:** RGB світлодіод, освітленість, колірна температура, автоматична система.*

А. В. Гадай
АВТОМАТИЧЕСКАЯ СИСТЕМА ИСКУССТВЕННОГО ОСВЕЩЕНИЯ С УПРАВЛЕНИЕМ ПО ЦВЕТОВОЙ ТЕМПЕРАТУРЕ

Искусственное освещение является одним из крупнейших потребителей электроэнергии, и в то же время перспективным способом экономии энергоресурсов, благодаря появлению и развитию более экономичных источников света. Недостаточная освещенность приводит к возникновению «заторможенного» состояния и замедление реакции человека. Это приводит к необходимости не только следить за соблюдением нормативного уровня освещенности, но и тщательно подбирать тип источника света и его цветовую температуру, в зависимости от вида работ и времени суток, в которое они выполняются. Разработана система, позволяющая воспроизводить важнейшие параметры естественного освещения – температуру и уровень освещенности, в соответствии с их естественными колебаниями и обеспечивает уменьшение расхода электроэнергии на искусственное освещение. Это дает возможность создания полной модели естественной световой атмосферы, которая положительно влияет на производительность труда, физическую и умственную активность человека.
***Ключевые слова:** RGB светодиод, освещенность, цветовая температура, автоматическая система.*

Introduction. Many physiological systems of the human body are regulated by internal biological clock. Attention, mental and physical activity, mood, body temperature and many other things change according to the 24-hour cycle. These changes are called circadian rhythm. At the end of the last century, scientists have found out that there is a biological "clockwork" in the brain of mammals, which coordinates the work of the whole body. Man has more than 100 circadian rhythms that interact with each other. For example, blood pressure and work of the brain are subjected to cyclic changes. Circadian rhythm is guided with cryptochrome (CRY) pigment. Cryptochrome proteins CRY1 and CRY2 absorb blue light as it is able to penetrate through several layers of cells in the best way. Signals from them come to the brain, which coordinates the work of trillions of individual "molecular clocks" which exist in the human body. This ensures 24-hour cycle of living.

Problem statement. Natural light and its rhythm during twenty-four hours and in the annual cycle plays a dominant role in synchronizing the biological clock as well as day-night and seasonal physiological and psychological rhythms. Light provides direct stimulatory effect on man's mood. However, it is impossible to fully provide room lighting only with natural light. Therefore, it is necessary to use automatic devices in order to create an artificial lighting system which is most comfortable for man.

Analysis of recent research and publications. Natural light is very important for man, improvement of his psychophysical condition and enhancement of productivity of work. Variation of intensity and spectral composition of light is typical for solar emission during the day and is a natural regulator of human life. In the daylight hours sunlight is characterized by high intensity, high color temperature and a high proportion of blue emission. In the evening hours the intensity of these components is greatly reduced. Man adapted to such fluctuations of light parameters. Change in mental and physical activity during 24 hours depends on the biological rhythm of a man, which is actually determined by three parameters: intensity, color temperature and the presence of the blue component of solar emission [1].

Analysis of existing systems of artificial lighting has shown that the most effective devices are those built on the principle of automatic control of lighting levels. However, they do not take into account the emission spectra of individual colour components of light.

The purpose of the article. It is proposed to use automatic lighting control systems, which allows reproducing the main parameters of natural light atmosphere - change in color temperature and brightness of lighting, in real time.

Basic materials of research. Today, it is virtually impossible to completely reproduce natural lighting parameters using the existing light sources. This is due to the difficulties of creating the light sources with the spectrum similar to the one of natural light. Changing the color temperature of the light source became technically possible only recently, in connection with the development and implementation of RGB light-emitting diodes (LEDs). Their feature is the inclusion of three light-emitting crystals in one case with a common optical system. This enabled getting all possible shades of colors distinguished by man by changing the current value independently for each of the crystals. RGB LEDs have the spectrum which is the most corresponding to the sensitivity of the human eye, and allow adjusting the color temperature [2].

The operational principle of the automatic artificial lighting system proposed is as follows (Fig. 1). In case of appearance of a man in the room, the motion sensor authorizes the microcontroller to read information from the illumination sensor about the intensity level of the emission spectra of red, green and blue components separately, and the total value of natural illumination level. The obtained value is compared with the set one, and if there is a mismatch, the intensity value of each colour is proportionally adjusted. This allows changing illumination level at a constant color temperature. Information about intensity of glowing of each color is fed from the microcontroller to the execution unit which generates control pulses for LED light source crystals.

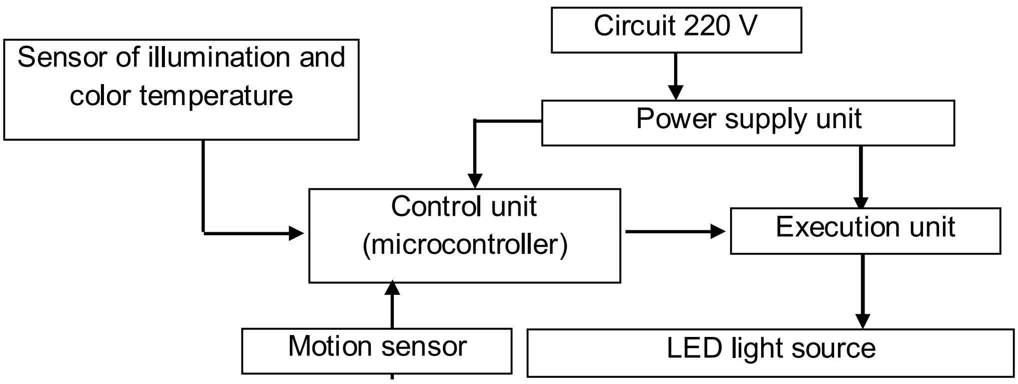

Fig. 1. **Functional diagram of automatic lighting control system**

Let us consider the work of each element of the system in detail.

The basis of the system is the control unit based on ATmega16L-8PU microcontroller by ATMEL company [3] (Fig. 2). Using a microcontroller in this system as a controlling device allows implementing in software the processing of information derived from sensors, its comparison with the data about the necessary level of illumination, adjustment of light parameters and generation of control pulses to control the light source.

To reproduce the desired color temperature it is enough to have a numerical value of two coordinates on the chromaticity diagram plane (Fig. 3). At that, the horizontal axis of the diagram characterizes saturation of particular color, and vertical one characterizes its hue.

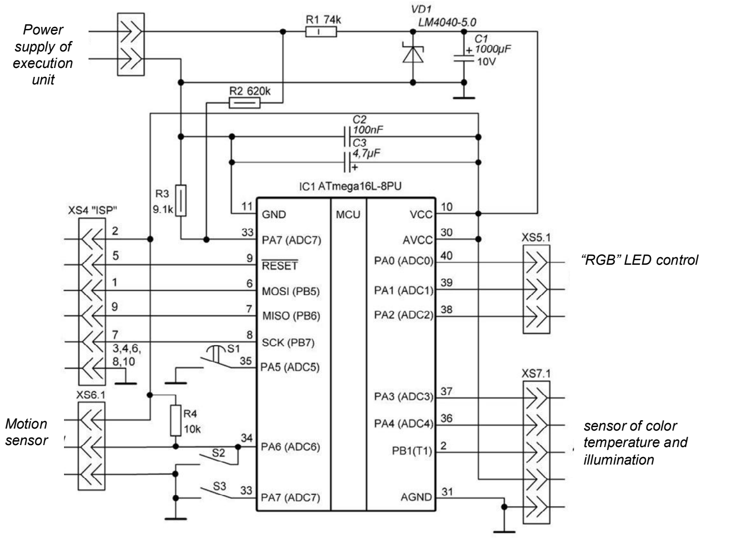

Fig. 2. **Principle diagram of the microcontroller control unit**

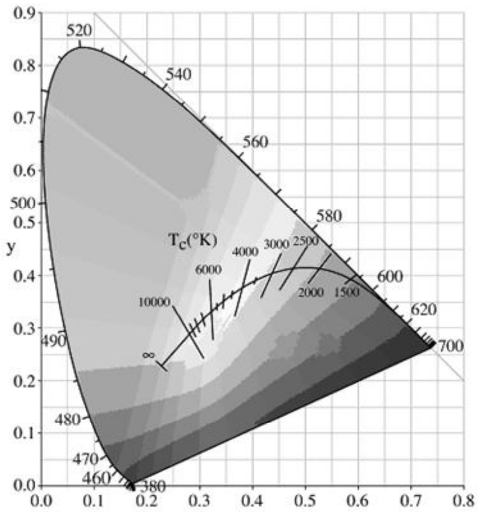

Fig. 3. **Diagram of chromaticity in x, y system**

The basis of the principle diagram (Fig. 4) is HV9961 LED driver, which allows stabilizing the current through the LED, regardless of external factors such as mains voltage fluctuations and temperature change. An additional advantage of using LED in the system is its emission spectrum that has the form corresponding to the sensitivity of the human eye. [4]

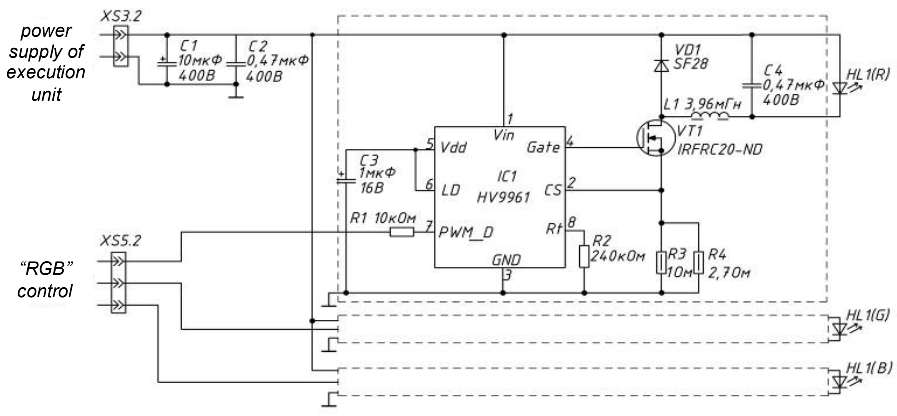

Fig. 4. **Principle diagram of the execution unit using RGB LED**

Exact maintaining of the set level of illumination and color temperature is achieved by introducing of color sensor into the system, which is located outside and changes the parameters of illumination in the room according to natural light changes. TCS3200 microcircuit chip - illumination-frequency converter – is used as the sensor of color temperature and illumination (Fig. 5 a).

The operation principle of the color temperature sensor is as follows (Fig. 5 b). RGB-filters disperse impinging light into red, green and blue components. Photodiode, which is located under the corresponding filter, converts brightness into current, and then operational amplifiers with current input convert the change of current into the change of frequency. Principle diagram of switching-on is shown in Fig. 5 c. This microcircuit chip provides linear dependence of frequency on illumination (about 1 kHz per 1lux) and spectral sensitivity close to the sensitivity of the human eye.

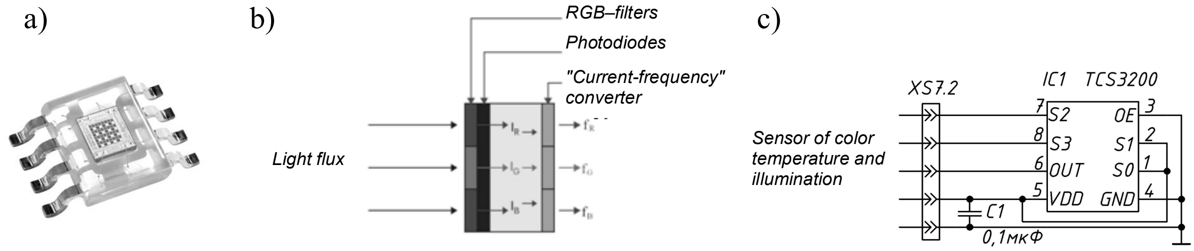

Fig. 5. **TCS3200 sensor of color temperature and illumination**

S0 and S1 leads are designed for scaling of the output frequency and consequently sensor sensitivity (Table 1). For this purpose, high (H) or low (L) logic levels are fed to the sensor leads.

Table 1. **Scaling of output frequency of the sensor**

S1	S0	Scaling of output frequency
L	L	Sensor switching-off
L	H	2% (0–12 kHz)
H	L	20% (0–120 kHz)
H	H	100% (0–600 kHz)

S2 and S3 leads are designed for switching to the OUT lead of one of the four arrays of photodiodes for reading of information about illumination level (Table 2).

Table 2. **Selection of photodiode**

S2	S3	Photodiode type
L	L	red
L	H	blue
H	L	white (without filter)
H	H	green

To read information about brightness of illumination in different spectra, corresponding logic levels are generated at ADC3 and ADC4 leads of the microcontroller. Linear dependence of the sensor frequency on illumination and closeness of its spectral sensitivity to the human eye sensitivity considerably simplify the program and allow achieving high accuracy in reproduction of the natural light spectrum.

Conclusions. From the given material, it follows that in addition to the positive impact on productivity of work and physical and mental activity of man, the proposed system provides significant savings of electricity compared to existing lighting systems. This device has a wide practical application, because it can be used in all areas of human activity where there is a need to create artificial lighting for a long time.

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