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DEVELOPMENT OF LED LIGHTING SYSTEM WITH DATA TRANSMISSION FUNCTION BASED ON VLC TECHNOLOGY

VLC ТЕХНОЛОГИЯСЫНА НЕГІЗДЕЛГЕН ДЕРЕКТЕРДІ ЖАСАУ ФУНКЦИЯСЫ БАР ЖАРЫҚДИОДТЫ ЖАРЫҚ БЕРУ ЖҮЙЕСІН ӘЗІРЛЕУ

РАЗРАБОТКА СВЕТОДИОДНОЙ СИСТЕМЫ ОСВЕЩЕНИЯ С ФУНКЦИЕЙ ПЕРЕДАЧИ ДАННЫХ НА ОСНОВЕ ТЕХНОЛОГИИ VLC

Abstract. In this paper, we study the amplitude-frequency characteristics of light-emitting diodes of visible light, the principle of their action, and the technical characteristics necessary for constructing networks using VLC technology.
Keywords: networks, data transmission, data reception, LEDs, Li-Fi, VLC, lighting device, software.

Аңдатпа. Осы мақалада жарық сәуле шығару жарық диодтарының амплитудалық-жиіліктік сипаттамаларын, олардың әрекет ету қағидатын және VLC технологиясын қолданып, желілерді құру үшін қажетті техникалық сипаттамалары зерттеледі.
Түйін сөздер: желілер, деректерді беру, деректерді қабылдау, жарық диодтары, Li-Fi, VLC, жарықтандыру құрылғысы, бағдарламалық қамтамасыз ету.

Аннотация. В данной статье изучаются амплитудно-частотные характеристики светоизлучающих диодов видимого света, принцип их действия и технические характеристики, необходимые для построения сетей с использованием технологии VLC.
Ключевые слова: сети, передача данных, прием данных, светодиоды, Li-Fi, VLC, осветительный прибор, программное обеспечение.

Wi-Fi is currently the most widely used data transmission technology. Its use helps to set up local computer networks and allows you to connect and transfer data to mobile devices. However, the technology has limits on the data rate associated with the wavelength of electromagnetic radiation. Based on medical studies, the radiation intensity in the vicinity of the router provided that a large number of users are connected may have a harmful effect on human health. One of the ways to improve data transmission characteristics in wireless networks can be the use of the optical wavelength range. This was made possible by the advent of white LEDs used for lighting. Since 2011, a new VLC (Visible Light Communication) technology has been rapidly developing, allowing the light source not only to illuminate the room but also to transmit information using the same light signal [1]. VLC uses visible light in the optical spectrum (about 400-800 THz). This technology can use fluorescent lamps for signaling at about 10Kbps or LEDs for signaling at about 500Mbps. The article describes a prototype of a new generation wireless data network Li-Fi (Light Fidelity or Light-based Wi-Fi) based on an LED system used to illuminate a room.

Since 2011, Harald Haas, a specialist in optical wireless data transmission and a professor at the University of Edinburgh (Edinburgh, United Kingdom), has seriously promoted a new technology for wireless data transmission via a flashing LED [2, 3]. At that time, most university professors decided that the idea was certainly interesting but hardly feasible. Four years later, Haas created the first router that works according to his concept. This technology is called Li-Fi. The new router showed amazing features. It surpassed Wi-Fi in speed by 100 times. The new router achieved a record data transfer rate of 224 Gbps in lab conditions. The test was carried out by the Estonian company Velmenni in the laboratory. Haas provided his first solar-powered router to make network access offline. Currently, the router has a stable data transfer rate of 10 Gbps due to the barely noticeable blinking of L.E.D [4].

To bring the first mass-produced systems to the European market, Li-Fi inventor Harald Haas merged his pure company with Lucibel to collectively develop and effectively drive innovation closer to the average consumer to make Li-Fi the mainstream for users to access the network.

The core of the technology works according to the following scheme. Three color channels thumbnail

L.E.D. (red, green, and blue) transmit data in parallel up to 3.5 Gbps. As a result, we can get 10 Gbps. Turning the lights on or off happens at breakneck speed, which creates a huge collection of binary data.

This is called orthogonal frequency division multiplexing (OFDM) digital modulation and allows millions of light beams to be transmitted at different intensities per second. Prof. Haas demonstrates this with an example of a showerhead that is worn strictly parallel, the light in a Li-Fi system works the same way.

Meanwhile, Chinese and German researchers became interested in researching this topic. Back in 2011, the Germans were able to achieve data transfer with a record speed of 800 Mbps at a distance of 1.8 m, and the Chinese connected 4 computers to the Internet at a speed of 150 Mbps. Prof. Haas stressed that lightwave technology is more secure than Wi-Fi. Wi-Fi networks are known to be easy to hack from the outside and intercept files as radio waves travel through walls outside.

Li-Fi, meanwhile, can theoretically only be used if you're in the same room as the transmitter and receiver, since light can't pass through walls. Thus, a reliable barrier is installed for violators, they will not be able to hack or intercept anything either from the street or even from the next room.

But first of all, the advantage of Li-Fi lies in its high speed and low power consumption (at best, the efficiency of standard routers reaches 5%).

Certainly, there are future prospects for this technology. Visible light waves have a very wide frequency band, 4 times as wide as radio waves. There is no risk of network congestion, and neither speed nor network performance is lost, like Wi-Fi [5].

LEDs are widespread. The infrastructure is almost there, and in addition, LEDs can perform two roles at the same time - a data transmitter and a light source. But there is another question: how well does the system work in a lit room or bright sunlight? However, developers have high hopes for VLC for data transmission using visible light [6].

The high data rate of Li-Fi already makes it possible to successfully transmit video streams in HD format, while maintaining the high energy efficiency of the system [7]. Another advantage over Wi-Fi is the accuracy and stability when connecting to the Internet inside buildings. The problem of the weak and discontinuous signal areas is solved due to the arrangement of distributed LED transmitters [8].

Most articles on data transmission using visible light provide a general scheme for the operation of VLC and Li-Fi technologies. However, circuit diagrams are rarely given. Usually, circuit diagrams are not described in detail and their operation is not discussed. This article describes in detail the scheme for transmitting an audio signal using a white LED used in lighting systems.

A block diagram of data transmission using an LED lighting device is shown in fig. 1. The transmission unit of the system consists of three parts:

1. Block 1 - preparation of data in a specific format. We use the STM 32 microcontroller, which allows us to match the signal coming from a personal computer (PC) with the lighting control system.

2. Block 2 - lighting control. This can be a standard driver built based on MAX16800 or LM3404HV microcircuits, which support dimming mode. You can also use the control scheme (Fig. 2).

3. Block 3 - LED lamp 3 (LFL), used by us in our experiments, consisting of 4 LED strips, each of which includes 8 serially connected Nichia LEDs with a power of 1 W.

The receiving unit also consists of three parts: a photodetector 4 based on a line of photodiodes, then a signal amplifier with a high and low pass filter 5, and a matching device 5. We also use the STM 32 microcontroller.

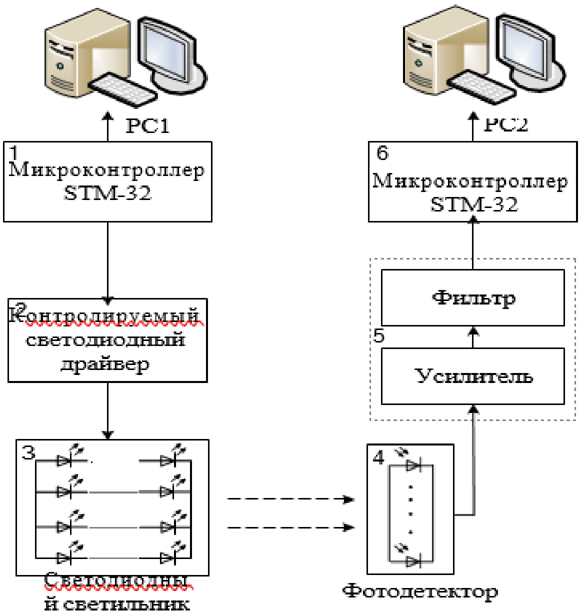

Figure 1. Structural diagram of a data transmission system based on VLC technology.

To demonstrate the operation and testing of such a circuit, we created a mock-up, the schematic diagram of which is shown in Fig. 2.

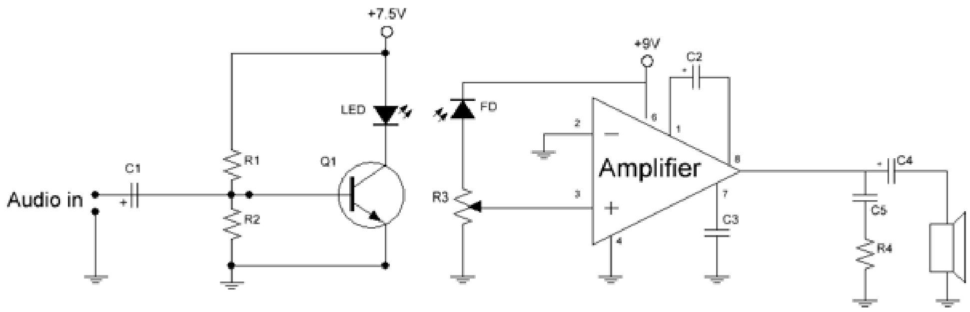

Figure 2. Schematic diagram of a sound transmission device using a white LED.

In this circuit, we used an amplifier assembled based on transistor Q1 as a control for the LED, which provides the necessary current for the LED. We worked with a BC337 transistor (originally with 2N2222A, and 2N4401 transistors). For the BC337 transistor, the values of the circuit elements were as follows: C1=2.2μF, R1=4.7kΩ, R2=1kΩ. A Nichia LED (NCSL219B) with a nominal value of 1 W was used. The lighting characteristics of the LED were previously well studied by us, and this LED was used by us in the design of lamps and the installation of the LED system for lighting office premises [9].

Studies of the frequency characteristics of this LED showed that for a signal frequency of 250 kHz, the signal does not change in amplitude. Further, at a frequency of 3.4 MHz, a decrease from the original signal to a level of 3 dB is observed. This means that data transmission using this LED in lighting systems will be limited to 3.2 Mbps.

A BPW34S photodiode was used in the receiving path. After the photodiode, the signal was amplified using an amplifier assembled on an LM386 chip. The ratings of the elements of this amplifier are as follows: C2=10μF, C3=0.1μF, C4=250μF, C2=0.05μF, R3=10kΩ, R4=10kΩ. For the normal operation of the above circuit, it is necessary to switch it on in a room without natural light in order to remove interference from the power supply of lighting devices. So, in bright sunlight, it was not possible to carry out data transmission.

If the input and output of this circuit are connected to microcontrollers (Fig. 1), then the sound is transmitted in real-time from one computer PC1 to another PC2.

To organize sound transmission from one personal computer to another, we used the STM32F4 Discovery microcontroller. For the transmitting channel, a USB input was used, the signal from which was converted using a 24-bit digital-to-analog converter and fed to the input of the LED control circuit.

An I/O port was used for the receiving channel. The signal to the port came from the amplifier after the C4 low-pass filter. Then the signal was digitized and transmitted via USB to a personal computer. The general block diagram of the STM32F4 Discovery board is shown in fig. 3. The choice of this board for the experiment was due to the fact that such an assembly has all the necessary components for working with sound: an analog input-output port, a 24-bit digital-to-analog converter connected to the audio connector, a USB port for data exchange with a computer. In addition, this board has a low cost (less than $10).

The microcontroller control program was standard. An example is an implementation made in the articles [9, 10]. When playing sound in real-time using microcontrollers, there was practically no distortion.

However, detailed studies of the frequency characteristics of the transmit-receive communication channel based on white light, described in this work, have not been carried out.

The appearance of the layout, assembled according to the scheme (Fig. 1), is shown in fig. 4.

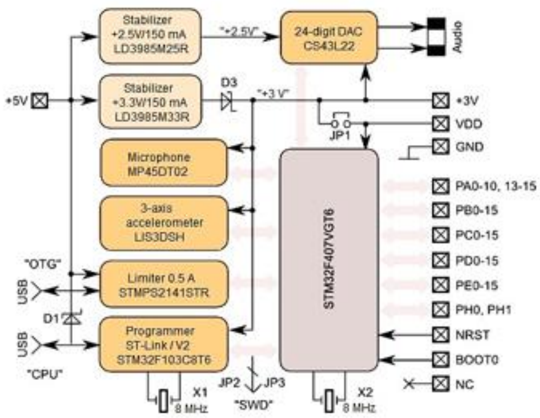

Figure 3. Block diagram of STM32F4. **Figure 4.** Appearance of the installation layout Discovery.

Headphones were used to control the sound quality, and a laptop was used to analyze the frequency characteristics of LEDs, program the microcontroller, and monitor the operation of the entire circuit.

The work demonstrates the transfer of data (sound) from one computer to another using VLC technology, while the implementation of the transfer was carried out using a simple circuit and a common element base. To organize a data transmission network, it is necessary to use data transmission protocols, such as TCP / IP, and at the physical level, the system described above uses microcontrollers. To increase the data transfer rate, it is necessary to use modulation of each color of the white LED. In this case, as a transmitting receiving path of the network, hardware is required that supports higher frequencies. So, for high frequencies of the order of 100 MHz, the sensitivity of the LED drops by 12-13 dB. This circumstance suggests that it is necessary to use more powerful LEDs or several LEDs in parallel for data transmission.

This work is intended for people conducting experiments on data transmission using white light LEDs.

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