Embedded LED lamp control system based on the ESP8266 microcontroller

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***Abstract*—The article provides an analysis of energy consumption in the field of artificial lighting and identifies areas for reducing energy consumption for lighting. The application of LED light sources with embedded systems is considered as one of the promising directions. Such a combination leads to increased energy efficiency of lighting devices and the possibility of their implementation in the technology of the "Internet of things" (IoT). The popularity of the concept of the "IoT" has forced manufacturers of semiconductor technology to develop microcontrollers with technical parameters that support the transmission of signals (information) via local or global networks. The advantages of the NodeMcu V2 board based on the ESP8266 microcontroller for developing embedded lighting control system for rooms implementing the concept of the IoT are demonstrated.**

Keywords—embedded system, LED, microcontroller, control, energy efficiency

I. INTRODUCTION

The problem of sustainable energy use against the backdrop of scarce resources and growing consumption is one of the most pressing problems of the global community, the solution of which is becoming a strategic objective for many countries. The steady growth of natural energy resource pricing, environmental concerns, abatement of pollutant and greenhouse gas emissions all make it crucial to find solutions for the problems of energy conservation and efficiency.

According to the International Energy Agency (IEA) [1], mains electric lighting consumes 19% of the global electricity generation of which 20 to 40% is spent on lighting in buildings [2, 3]. Power consumption associated with lighting accounts for 6-8% of greenhouse gas emissions [4].

In Kazakhstan, artificial lighting accounts for 12-14% of total power consumption [5]. Lighting devices in public and residential buildings consume some 40-60% of that power, which is 2-3 times higher than in European countries [6].

Based on its analysis of the global economic and energy efficiency trends, the IEA has made a forecast that the demand for artificial lighting is going to grow by 60% over the next 20 years. Without advanced technology and new energy efficiency policies, such growth in electricity generation will result in increased consumption of energy resources, which are mostly non-renewable, and in degradation of the environment due to the higher hydrocarbon fuel-associated emissions.

Lighting is a segment with high energy conservation potential. It is estimated that power consumption in Kazakhstan can be reduced by some 30%-35% [7].

Investing in energy-efficient lighting is also one of the most cost-effective ways to reduce CO2 emissions [8].

Studies show that modern technology will reduce electricity for lighting by 50% [9,10].

One way to achieve significant energy efficiency is to use new semiconductor (LED) light sources and the development of lighting devices based on them. World experience shows that street and office lighting based on the automation of LED technology improves the quality of life while ensuring economic benefits and environmental safety.

There are two directions of technological development in the field of electric lighting. The first is to improve the light-emitting components and designs lighting equipment: an increase the light output of the light source, reduction of power density; improving lighting and energy characteristics. The second trend involves the development of methods and modes of operation of lighting products: optimizing the placement of lamps depending on the purpose of visual tasks; efficient use of natural light with view of the diurnal cycle, seasonal and climatic region; implementation of lighting control systems.

With the introduction of digitalization and the creation of smart homes and cities, great interest is shown in the development of Internet devices. The most common are devices that have their own monitoring and control measurement systems. This became possible with the advent of microcontrollers with a small size and high technical characteristics. Currently, much attention is given to the creation of effective devices and systems with embedded intelligent controls [11, 12].

A key factor in the work of embedded systems and their feature is efficiency. This means that it is not always enough to perform a given function to solve a task. The solution must be unconventional. For example, a system must be fast or energy efficient, or cheap. And therein lies the difference between developing embedded systems and traditional software.

The reason for these restrictions is that for most of these devices it is very important to reduce their cost as, for example, for consumer electronics devices.

The embedded system is the applied computer system created for management of a number of functions. Because of the rapidly evolving technology, the importance of embedded systems is a highly fluctuating definition. Development of technologies leads to decrease in cost value and allows to implement different equipment and program components in the embedded systems. The embedded system intended for a specific objective usually consists of inputs, outputs and small processing unit. The majority of the embedded systems are jet systems. The information received by the system is constantly processed, and the system acts information on the basis that changes depending on the interaction system and environment.

A variety and range of complexity of such systems are huge. These are systems from the controller of office door lock or a garland to infocommunication "stuffing" of the plants automatic machines, intellectual power generating systems, buildings, the transport systems and even the «smart» cities. Examples of some largest scopes: industrial automatic equipment, transport, avionics and military equipment, telecommunications, medicine, intellectual building, housing and public utilities, household appliances, etc.

Simple embedded system includes [13]:

– microprocessor module with memory;

– peripheral system (sensors, executive elements and control units for communication with the control object, user interface device);

– electric power supply system;

– design of the device;

– software for control.

The main features of the embedded system are:

– real-time operation;

– different, often heavy, operating conditions;

– autonomy of work;

– high requirements for reliability and safety of functioning;

– limited resources.

Significant progresses in microelectronics technology have made it possible to increase miniaturization of embedded systems. This trend leads to the development of tiny embedded systems integrated into an increasing number of household items and will create a world of smart devices.

II. MAIN PART OF THE RESEARCH

To implement lighting control systems in the premises companies offer a wide range of functionality based on modern sensors and software. Such systems are quite difficult to connect and operate, and also have a high cost, which is not attractive even if you save energy and save the environment.

The popularization of the Internet of Things technology has led to an increase in the production of miniature microcontrollers with the additional ability to control various devices (for example, lighting lamps) from a distance by transmitting a signal to a local network or the Internet via Wi-Fi, Bluetooth, Ethernet or a cloud server.

Structural scheme of the embedded lighting control system in the room is shown in Fig. 1. The LEDs in the lighting device can be controlled automatically (software) or remotely (by the user) from a mobile device.

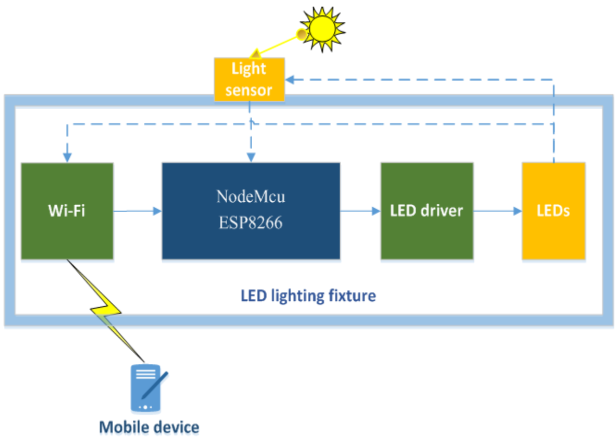


Fig. 1. General scheme of the embedded lighting control system

Automatic control. The brightness value of the LED is determined by the photoresistor, the analog signal from thephotoresistor goes to the microcontroller, where it is converted to a PWM signal. The PWM signal is sent to the LED driver. The driver sets the brightness value on the LEDs in accordance with the received signal.

Remote control. The change of mode to remote control occurs through the mobile device by the user. The wireless connection of the microcontroller with the mobile device is provided through the Wi-Fi module. Control from mobile device is carried out using a graphical interface. The brightness value of the LED is set by the user, which is transmitted to the microcontroller and converted into a PWM signal. The LED driver sets the brightness value in accordance with the received PWM signal.

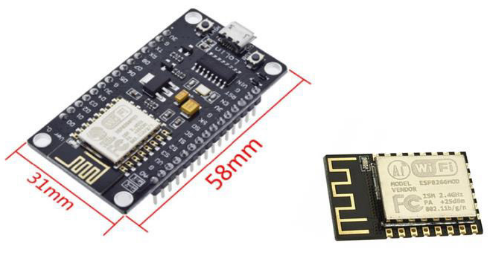
The market for manufacturers of microprocessor technology provides an extensive selection of microcontrollers for developing devices for the Internet of things. It is worth noting that the initial process of developing a new device involves the stages of debugging and testing the device. For a rather long period of time, two debug boards Arduino and STM32 occupied the leading position in the engineering community. Debug boards have gained popularity due to a number of positive aspects, the main of which are the ability to collect a prototype of the device under development without soldering, using a breadboard and connecting wires. The second point is not so clear, this is the ability to flash the microcontroller directly without additional programmers.

The above brands include a wide range of debug boards. Despite this, the microprocessor technology market is constantly being updated and provides an opportunity for an alternative choice. Our attention was drawn to the ESP line of microprocessors.

ESP8266 is microcontroller of the Chinese producer Espressif Systems with a Wi-Fi interface. The ESP8266 is an on-chip SoC that includes 32-bit microcontroller Tensilica, standard digital peripheral interfaces, antenna switches, a radio frequency simulator, a power amplifier, a low-noise receiving amplifier, filters and power management modules, all located on a small chip size (Figure 2). In addition to Wi-Fi, the microcontroller is distinguished by the absence of a user non-volatile memory on the chip; user programs are executed from external memory with the SPI interface by dynamically loading the necessary program elements.

The microcontroller attracted attention in connection with the release of products based on it at an unusually low price. For comparison, today its cost is about $ 2.5, which equaled the cost of the Arduino Uno board [14].

Applications for the ESP8266 include automation systems, various smart home systems (wireless control, wireless sockets, temperature control, addition to alarm systems), mobile electronics, ID tags, children's toys, Mesh networks.



a) b)

Fig. 2. Appearance of the NodeMcu board (a) and the microcontroller ESP8266 with Wi-Fi module (b)

On the basis of ESP8266 microcontroller has an extensive range of debugging boards [15]. We have been chosen NodeMcu v2 ESP8266-12E.

The NodeMcu v2 was designed specifically for the Internet of Things (IoT). The NodeMcu v2 board contains ESP-12E chip with integrated ESP8266 microcontroller with a clock frequency of 80 MHz and a 4 MB flash memory. ESP8266 includes a Wi-Fi transceiver, so you can not only connect to a Wi-Fi network but also create your own network.

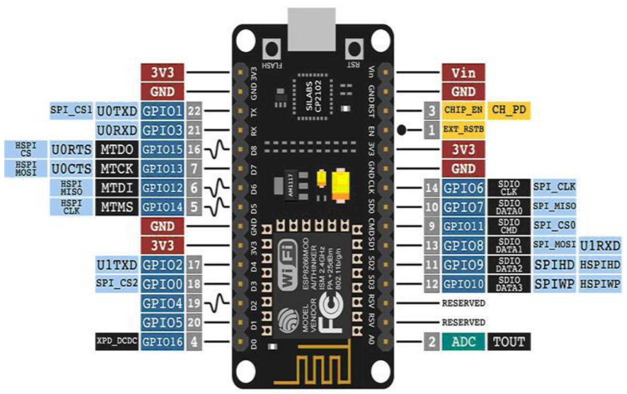


Fig. 3. Pinout for NodeMcu v2 board on ESP8266-12E

For programming NodeMcu, or rather ESP-12E, the board has a micro USB connector and a USB-UART CP2102 controller (Silicon Labs), which converts the USB signal to a serial port. The NodeMcu module is powered through the built-in micro USB connector or from an external 5 V voltage source connected to the VIN and GND pin. Since the operating voltage of the ESP8266 is from 3 V to 3.6 V., the voltage regulator AMS1117 is installed on the board with an output voltage of 3.3 V and a current of up to 600 mA. For convenience and the ability to connect external devices (sensors), 3.3 V is additionally output to the side contacts of the NodeMcu board with the designation 3V3. [16].

NodeMCU has total 30 pins output from both sides of the board, of which 17 are GPIO pins. The pinout for the NodeMcu v2 board on the ESP8266-12E used in our project is shown in Fig. 3 [17].With the help of boards based on the ESP8266 microcircuit it became possible to implement intelligent projects. This is due to the function of the microcontroller to act as a web server and connect to an existing network, and also set up a network of its own [18].

III. Practical Results

A schematic diagram for designing an experimental layout is shown in Fig. 4. Despite the simplicity of this circuit, the possibilities of the proposed system are quite wide. The system allows data exchange with a mobile device and a personal computer.

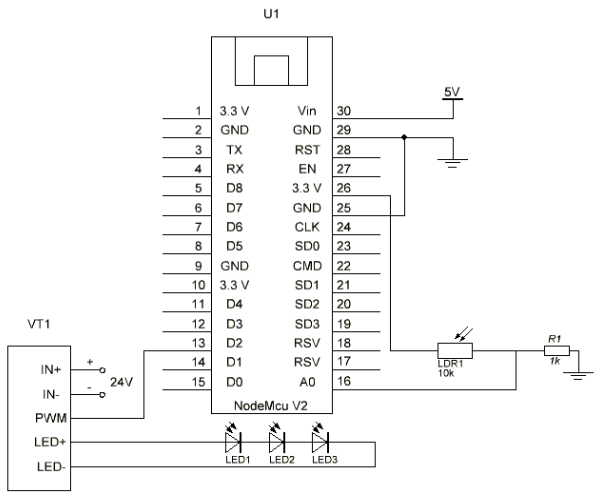


Fig. 4. Circuit diagram

To provide communication with a mobile device and to set the operating modes of the LEDs, an algorithm was developed (Fig. 5).

The popularity of the concept of “Internet of things” gave impetus not only to the development of microprocessor technology, but also to software. The RemoteXY application was used to develop a user interface and to control the level of illumination through a mobile phone. The RemoteXY system is presented in the form of two modules: the editor of mobile graphical interfaces for controlling the controller, as well as the RemoteXY mobile application that allows you to connect to the controller and display graphical interfaces [19].

It should be noted that RemoteXY offers a large list of components for design. For communication between the controller and the mobile device you can use Bluetooth, WiFi in client and access point mode, Ethernet by IP address or URL, Internet from anywhere through a cloud server. Widely used integrated development environments such as Arduino IDE, FLProg IDE, MPIDE are supported. The interface source generator works with the main types of Arduino, WeMos, ChipKIT microcontroller boards, as well as NodeMCU V2, NodeMCU V3 boards.

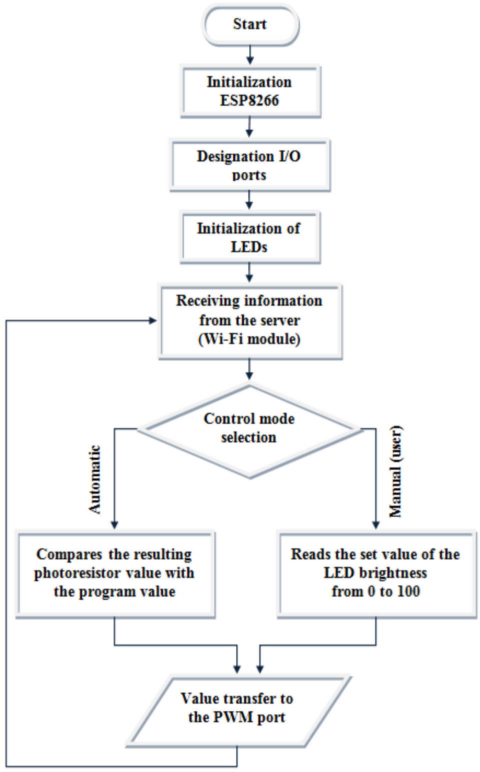


Fig. 5. The algorithm of the embedded control system

The developed interface for a mobile phone is shown in Fig. 6. The interface offers a switch between automatic and manual modes of the system and the ability to regulate each mode separately.

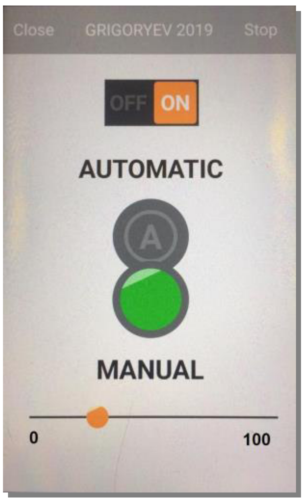


Fig. 6. The mobile device interface

In our project, the ESP8266 module is configured as a standalone Wi-Fi access point. For this mode of operation, no binding to an existing Wi-Fi network is required. To connect, the mobile phone is connected to the access point we created (in our case, Grigoryev2019).

It should be noted that the configuration of the graphical interface is recorded and stored in the controller. When connecting, there is no interaction with third-party servers in order to load the graphical interface. The user interface configuration is loaded into the mobile application from the controller.

Conclusion

In the era of the Internet of Things (IoT), classic indoor lighting control systems give way to embedded systems based on modern microcontrollers that combine the necessary technical parameters, small size, low cost and the ability to develop lighting devices that support the IoT concept.

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