ISSN 2706-655X Vol.5, Issue 6: 37-45, DOI: 10.25236/IJFET.2023.050606

Design and implementation of a multi-functional desk lamp with intelligent posture correction based on MCU

Jingzhuo Xu[1], Jingyi Xu[2], Bojun Wang[2], Hongyu Wang[3,*]

[1]School of Computer Engineering, Tongda College of Nanjing University of Posts and Telecommunications, Yangzhou, 225127, China
[2]School of Communication Engineering, Tongda College of Nanjing University of Posts and Telecommunications, Yangzhou, 225127, China
[3]School of Electronic Engineering, Tongda College of Nanjing University of Posts and Telecommunications, Yangzhou, 225127, China
[*]Corresponding author: 20060050@njupt.edu.cn

Abstract: *With the improvement of people's living standards, more and more people have become accustomed to sitting in front of computers for long periods of time for work or study, which can lead to poor sitting posture habits. This paper aims to design an intelligent desk lamp that combines Bluetooth technology with remote communication technology to improve people's quality of life by correcting sitting posture and providing comfortable lighting experiences. The design uses the STC89C52 as the main control chip, and combines infrared sensing, photoresistor, and Bluetooth HC05 remote communication to detect and control parameters such as human sitting posture and ambient light. Experimental results show that the intelligent desk lamp designed in this paper has excellent lighting effects and can adjust brightness adaptively. In terms of sitting posture correction, the desk lamp can accurately detect human sitting posture and remind users to adjust their posture in a timely manner. In addition, the Bluetooth HC05 remote communication module enables communication with mobile phones and other devices, and facilitates remote control through sending specific AT commands or defining specific communication protocols. The intelligent desk lamp designed in this paper not only improves the comfort and productivity of office environments, but also provides a useful application of smart home technology in daily life. In the future, with the increasing demand for smart home technology, the market prospects of intelligent desk lamps, especially those with remote communication functions, will become even broader.*

Keywords: *microcontroller; intelligent desk lamp; infrared sensing; bluetooth communication*

1. Research background

With the continuous and rapid development of the social economy, microcontrollers and communication devices have undergone significant innovations, and smart devices have a promising future[1]. Smart home products have emerged as an indispensable part of people's lives, and the demand for desk lamps has evolved from the initial requirement of fixed brightness to the current automatic light-sensing dimming[2]. Among them, the smart multifunctional desk lamp, as an important smart home product, not only has lighting functions but also can implement various practical functions through human-computer interaction technology, such as remote communication, voice prompt, greatly facilitating people's lives. The application of MCU technology further improves the interaction performance and user experience of smart desk lamps, allowing people to enjoy high-quality life and complete various tasks more conveniently and efficiently. This article will provide a detailed introduction to the design principles and implementation methods of smart desk lamps, as well as prospects for their future development.

2. The overall structure of the smart desk lamp

The overall structure of a smart desk lamp generally includes components such as a lamp body, a controller, sensors, and a communication module. The lamp body usually consists of parts such as a lamp base, lamp head, and lampshade, with the main function of providing lighting services. The controller is the core part of the smart desk lamp, which can be automatically or manually controlled according to the user's needs, and works in coordination with the sensors and communication module to achieve intelligent management of the lamp. The sensor is mainly used to perceive the surrounding environment, with a photoresistor used to detect the intensity of external light, so as to automatically adjust the brightness of the lamp to adapt to the brightness level of the environment[3]. At the same time, the human infrared sensor can detect whether someone is approaching the desk lamp, realizing automatic switching of the lamp and thus improving energy utilization efficiency and convenience[4] . The communication module adopts Bluetooth technology, which is used for wireless communication with a mobile phone, enabling the user to control various settings and functions of the lamp through a mobile application, such as light brightness, color, and timing functions. This allows the user to achieve remote control through a corresponding app or program on their phone. The design of the overall structure needs to consider multiple factors, such as human-computer interaction, energy conservation and environmental protection, safety, etc., in order to meet the user's needs and enhance their experience. The overall system design is shown in Figure 1.

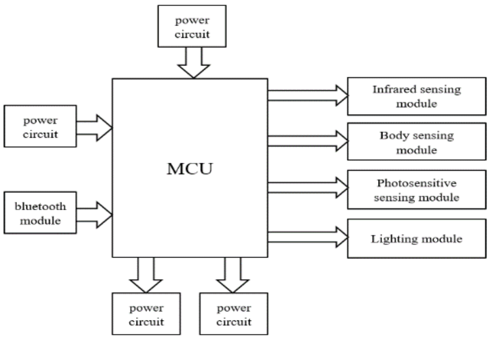

Figure 1: System diagram

3. Hardware circuit design of smart desk lamp

3.1 Main Control Chip Selection

The minimum system of the microcontroller unit (MCU) consists of the STC89C52 MCU chip, crystal oscillator circuit, reset circuit, and power supply circuit, which features high speed, low power consumption, and low cost, and is widely used in various embedded systems. The circuit of the MUC system is shown in Figure 2.

1) Crystal oscillator: The crystal oscillator is the clock source of the microcontroller, and an external 12MHz or 11.0592MHz crystal oscillator can be selected. The STC89C52 chip requires an 11.0592MHz crystal oscillator to provide the system clock.

2) Reset circuit: The microcontroller needs a reset circuit when starting up to enter normal operation. A reset circuit chip or an RC reset circuit can be used.

3) Expansion interface: To implement different functions, various peripherals such as LEDs, LCDs, keyboards, and serial ports need to be connected through the expansion interface, with the serial port introduced as listed in Table 1.

Table 1: Introduction to Serial Ports of the Main Control Chip

Index number	Serial port	Serial port function
1	P1.0	External Interrupt0/T2
2	P1.1	External Interrupt1/T2EX
10	P3.0	RXD: Serial port input
11	P3.1	TXD: serial port output
15	P3.5	T1: External input terminal of Timer/Counter
16	P3.6	WR: External Data Memory Write Enable Signal Output
17	P3.7	RD: External Data Memory Read Enable Signal Output

ISSN 2706-655X Vol.5, Issue 6: 37-45, DOI: 10.25236/IJFET.2023.050606

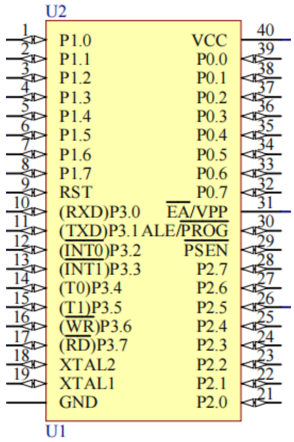

Figure 2: MCU System Circuit Diagram

3.2 LED driver module

The main function of the LED driver module is to control the on and off states and brightness adjustment of the LED lights. In this module, the LED lights are divided into three channels, each of which contains four LED lights. The on and off states of each channel of LED lights are controlled by a S8050 transistor, which works by controlling the base current of the transistor to adjust its amplification factor, thus realizing the on and off states of the LED lights[5].

As for brightness adjustment, this module uses Pulse Width Modulation (PWM) control. PWM is a method of controlling the average voltage or current of a circuit by changing the duty cycle of the signal. In the LED driver module, the PWM signal output by the microcontroller is input to the LED driver circuit, and after passing through an RC filter circuit, it is sent to the control terminal of the three transistors that are adjustable by three variable resistors (or digital potentiometers)[6]. By changing the value of the variable resistors, the working state of the transistors can be adjusted to change the brightness of the LED lights. The LED driver circuit is shown in Figure 3.

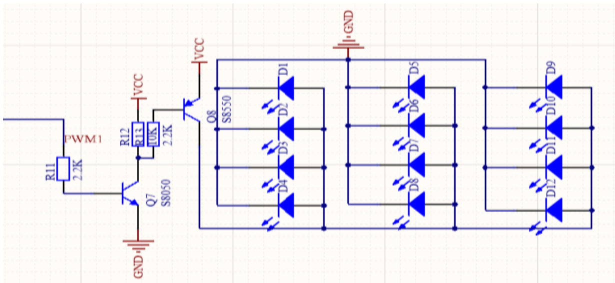

Figure 3: LED driver circuit diagram

3.3 Design of a Photosensitive Circuit

The photoresistor and ADC0832 analog-to-digital conversion chip are used to implement the photoelectric sensing circuit module. The photoresistor detects the brightness of the light and changes its resistance value according to the brightness value. The ADC0832 chip converts the analog electrical signal output by the photoresistor into a digital signal, which is then transmitted to the single-chip microcomputer for processing and control.

To achieve voltage division, the photoresistor R1 and a 10KΩ fixed resistor R6 are connected in series, so that the voltage at both ends of the resistor R6 can reflect the current ambient light intensity. Specifically, when the ambient light is strong, the resistance value of the photoresistor R1 is small, causing the voltage value at both ends of the resistor R6 to increase; conversely, when the light is weak, the resistance value of the photoresistor R1 is large, causing the voltage value at both ends of the resistor R6 to decrease accordingly[7].

In the specific implementation, the photoresistor and the ADC0832 chip need to be connected through a circuit. The photoresistor is connected to the AIN0 channel of the ADC0832 chip. The VCC of the

ISSN 2706-655X Vol.5, Issue 6: 37-45, DOI: 10.25236/IJFET.2023.050606

ADC0832 chip is connected to the 5V power supply of the single-chip microcomputer, and the GND of the ADC0832 chip is connected to the ground of the single-chip microcomputer. At the same time, the CS, RD, and WR pins of the ADC0832 chip are connected to the corresponding GPIO ports of the single-chip microcomputer for controlling the read and write operations of the ADC0832 chip. The analog-to-digital conversion circuit is shown in Figure 4.

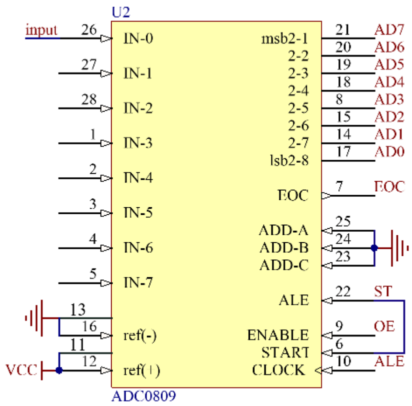

Figure 4: Analog-to-Digital Converter Circuit Diagram

3.4 Pyroelectric infrared sensor

The Passive Infrared (PIR) sensor is a pyroelectric type infrared sensor based on the principle of thermoelectric effect. It has high sensitivity and can detect infrared radiation emitted by human bodies, thus outputting an electrical signal[8] . It mainly consists of the PIR sensor and signal processing circuit.

The PIR sensor is a component that generates a weak electrical signal based on the variation of temperature using special materials. When a human body enters the sensing range of the sensor, its body temperature will produce weak heat radiation, which is detected by the sensor. The sensor outputs the detected weak electrical signal to the signal processing circuit for further processing.

The signal processing circuit mainly consists of a preamplifier, a filter, a comparator, and an output circuit. The preamplifier amplifies the weak electrical signal output by the sensor, while the filter filters the amplified signal to eliminate noise interference, ensuring the stability and reliability of the signal. The module uses a fully automatic repeat triggering sensing mode, which outputs a high-level signal when a person is within the sensing range of the lamp; after the person leaves the sensing range of the lamp, the high-level signal is automatically turned off with a delay[9] . The output circuit processes the output signal of the comparator and outputs a digital signal to the microcontroller or other devices to achieve the function of human body detection. The infrared sensing circuit is shown in Figure 5.

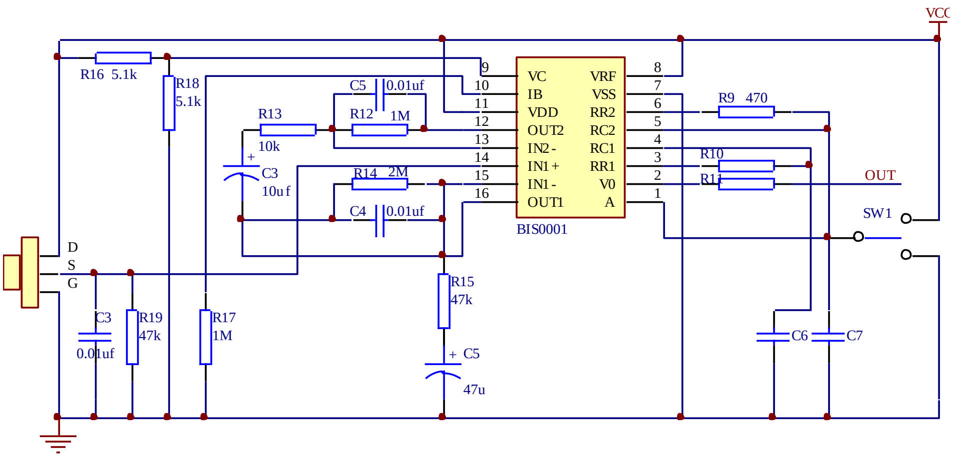

Figure 5: Infrared sensing circuit diagram

3.5 Remote communication design

The remote communication module is implemented using the Bluetooth HC05 module, with pin 2

ISSN 2706-655X Vol.5, Issue 6: 37-45, DOI: 10.25236/IJFET.2023.050606

connected to VCC, pin 3 connected to ground, and pins 4 and 5 connected to the P3.0 and P3.1 pins of the microcontroller, respectively[10] . Using the serial communication feature of the HC05, it is connected to the UART serial port of the microcontroller, enabling communication with a smartphone or other Bluetooth device. The HC05 can be configured and controlled using AT commands.

In practice, we can connect the TXD pin of the Bluetooth module to the RXD pin of the microcontroller, and connect the RXD pin of the Bluetooth module to the TXD pin of the microcontroller, enabling bidirectional data transmission. In the microcontroller code, we need to initialize the UART module and write functions for data transmission and reception, enabling communication with the Bluetooth module.

The HC-05 embedded Bluetooth serial communication module has two modes of operation: command response mode and auto-connection mode[11] . In auto-connection mode, the HC-05 will automatically connect to a pre-set Bluetooth device and transfer data. In command response mode, users can send various AT commands to set control parameters or issue control commands. The module can respond to all AT commands.

We also need to design a remote communication protocol, which can be used to develop an app for smartphones or other remote devices. A communication protocol can be defined using a format such as JSON, clearly specifying the data format and meaning of the communication. The Bluetooth module design is shown in Figure 6.

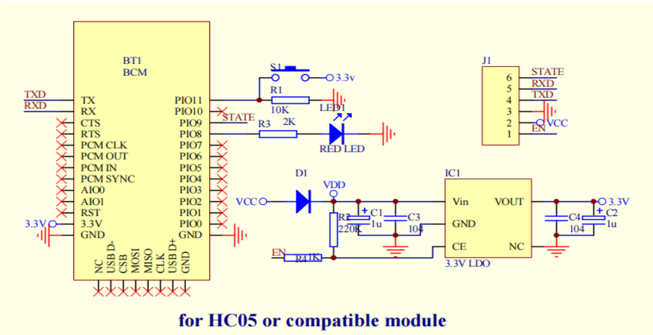

Figure 6: Bluetooth module design diagram

4. Design of an Intelligent Desk Lamp Software System

Programming Environment Introduction:

This design uses Keil uVision 5. Compared to other environments, Keil uVision 5 is an embedded development environment with support for multiple programming languages, integrated development environment, multiple microcontroller support, automated build tools, built-in debugger, and visual programming. It can help developers quickly build, debug, and deploy embedded systems, while improving development efficiency and accuracy. Whether for professional embedded system developers or beginners, Keil uVision 5 is a powerful tool.

Main Program Design:

The system flow is shown in Figure 7. First, the initialization of the microcontroller and sensors lays the foundation for subsequent information acquisition, processing, and display[12] . Then enter the automatic mode, use the photoresistor circuit to detect the ambient light brightness, determine whether to turn on the desk lamp, and adjust the brightness according to the PWM controlled by the brightness. Start the human body induction module to detect whether there are people around, and if there are people, adjust the brightness to the maximum; if there are no people, delay for a certain time and then turn off the desk lamp[13] . Start the pyroelectric infrared induction module. When the user's posture is incorrect, the buzzer will sound an alarm. Enter manual mode and adjust the brightness using the plus and minus buttons. The mobile phone can remotely control the LED light switch and brightness adjustment functions through the Bluetooth HC05 module.

ISSN 2706-655X Vol.5, Issue 6: 37-45, DOI: 10.25236/IJFET.2023.050606

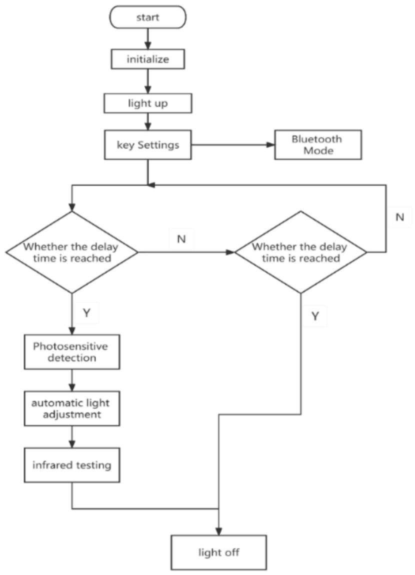

Figure 7: System Flowchart

Light-sensitive program design:

1) Initialize the photoresistor sensing circuit module, including pin definitions, and initialization of the analog-to-digital conversion module (ADC0832).

2) Use the analog-to-digital conversion module to convert the analog voltage signal collected by the photoresistor sensing component into a digital signal, thereby obtaining the value of the light intensity. The conversion method is: connect the CS terminal of the AD0832 chip to the P1^4 terminal of the microcontroller, connect the DOUT terminal of the ADC0832 to the P1^5 terminal of the microcontroller, and connect the AIN3 port of the ADC0832 to the photoresistor sensing component to achieve analog-to-digital conversion of the light intensity.

3) Determine whether the light intensity value is lower than the set threshold. If it is lower, turn on the desk lamp; otherwise, turn off the desk lamp.

4) Adjust the PWM according to the light intensity value to control the brightness of the LED lamp [14] . When the light intensity value is low, that is, the environment is dark, the brightness of the desk lamp should be higher; when the light intensity value is high, that is, the environment is bright, the brightness of the desk lamp should be lowered.

5) In automatic mode, periodically detect the light intensity through a timer and interrupt, and adjust the PWM according to the light intensity value to achieve the function of automatically adjusting the brightness of the desk lamp. The photoresistor sensing process is shown in Figure 8.

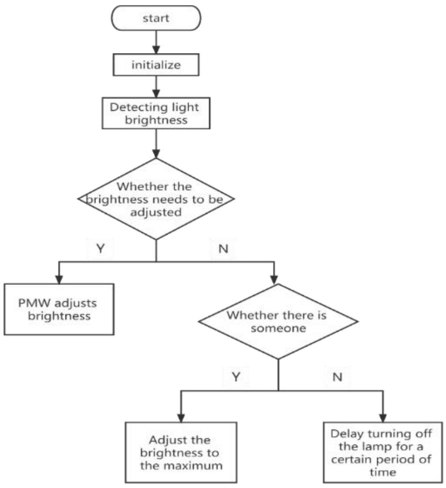

Figure 8: Light-sensitive sensing process flowchart

Infrared induction program design:

Initialize the infrared induction module, including pin and parameter settings. Then activate the infrared induction module to start detecting the user's posture. Obtain the output signal of the infrared induction module and convert it into a digital signal for processing.

Analyze and process the data, determine whether the user's posture deviation is too large or incorrect[15] . If the user's posture deviation is detected to be too large or incorrect, trigger the buzzer to sound an alarm to remind the user to correct their posture, in order to prevent myopia and ensure good sitting habits[16] . Repeat the detection and processing of the infrared induction module until the user turns off the desk lamp or exits the program. The infrared induction process is shown in Figure 9.

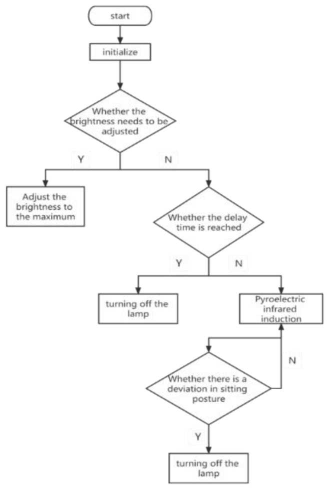

Figure 9: Infrared induction process flowchart

Bluetooth Program Design:

Initialize the Bluetooth module: Firstly, it is necessary to initialize the Bluetooth module, open the corresponding serial port or IO port, and perform the initialization settings of the Bluetooth module.

Establish Bluetooth connection: A Bluetooth connection is required between the Bluetooth module and the phone or other Bluetooth devices. Usually, the pairing of Bluetooth devices is used to establish the connection.

Realize data transmission: After establishing the Bluetooth connection, data transmission needs to be implemented, including sending and receiving data[17]. Usually, serial communication is used for data transmission, sending data to the phone or other Bluetooth devices through the Bluetooth module, or receiving data sent by the phone or other Bluetooth devices.

Data processing: After receiving the data sent by the phone or other Bluetooth devices, the data needs to be processed accordingly. For example, for the functions of LED lights on/off, brightness adjustment, and learning mode setting, the corresponding operation needs to be performed after receiving the corresponding instructions. The Bluetooth control process is shown in Figure 10.

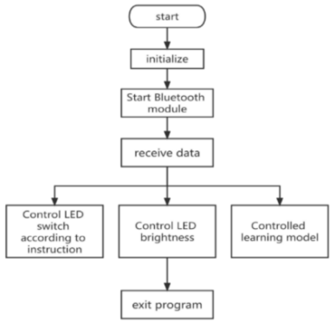

Figure 10: Bluetooth Control Flowchart

ISSN 2706-655X Vol.5, Issue 6: 37-45, DOI: 10.25236/IJFET.2023.050606

5. Smart desk lamp performance testing

Test plan:

Automatic mode testing:

Step 1: Connect the smart desk lamp system to the power source and place it in a well-lit environment.

Step 2: Observe the brightness of the LED lamp and determine if it can automatically adjust the brightness, ensuring that the photosensitive sensing circuit, ADC0832 analog-to-digital conversion chip, LED driving circuit, and other modules are working properly.

Step 3: Cover the photosensitive sensing circuit with your hand and observe if the LED lamp automatically adjusts the brightness, ensuring that the photosensitive sensing circuit module is working properly.

Step 4: Use a handheld light dimmer to simulate different brightness environments and observe if the LED lamp brightness changes accordingly, ensuring that the PWM control module is working properly.

Step 5: In the absence of anyone, observe if the LED lamp can automatically turn off after a certain period of time, ensuring that the human body induction module is working properly. The actual smart desk lamp is shown in Figure 11.

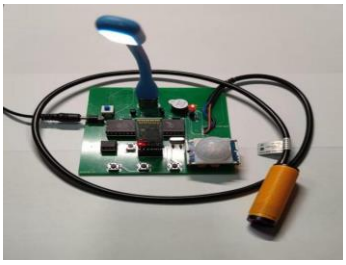

Figure 11: Picture of an actual smart desk lamp

Manual mode testing:

Enter manual mode and adjust the LED brightness through the plus and minus buttons. Observe if the LED light works according to the set brightness to ensure the normal operation of the manual control module.

Remote control testing:

Step 1: Open the Bluetooth software and connect to the intelligent desk lamp.

Step 2: Test the switch and observe whether the LED light can be turned on or off.

Step 3: Test the brightness adjustment function and observe whether the LED light can work according to the set brightness.

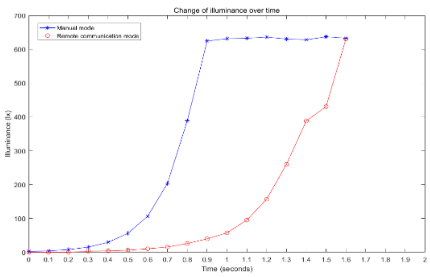

Figure 12: Curve of light intensity over time in different modes

Test Results:

The results of the performance testing showed that the manual mode of the smart desk lamp had slightly better illumination and response time compared to the Bluetooth mode. The curve of light intensity change over time is shown in Figure 12.

All test results were successful, and all modules of the smart desk lamp system were functioning normally, meeting the design requirements.

ISSN 2706-655X Vol.5, Issue 6: 37-45, DOI: 10.25236/IJFET.2023.050606

6. Summary

As an intelligent lighting product, the intelligent desk lamp has the advantages of energy saving, environmental protection, and intelligence, and has been widely used in modern home life. Based on the design of photo-sensitive circuit, pyroelectric infrared induction module, LED driving circuit, and human body sensing module, this project realizes the switching between automatic mode and manual mode, automatic adjustment of LED lamp brightness, application of human body sensing module, sitting posture detection of pyroelectric infrared induction module, remote control of Bluetooth module and other functions. In testing, the intelligent desk lamp successfully achieved photo-sensitive induction, human body sensing, and pyroelectric infrared sensing in automatic mode, as well as brightness adjustment and learning mode setting in manual mode. At the same time, in the remote control test, the intelligent desk lamp successfully realized remote switch, brightness adjustment and learning mode setting through the Bluetooth module. Overall, the intelligent desk lamp design of this project has practicality, reliability, and innovation, and can provide users with a more comfortable and intelligent home life experience.

Acknowledgements

Innovation and Entrepreneurship Training Program for College Students in Jiangsu Province; Innovation and Entrepreneurship Training Program for College Students in Nanjing University of Posts and Telecommunications Tongda College; Project number: 202213989002Y.

References

[1] Yanqiong Yu. Design and exploration of an intelligent home environment monitoring system based on STC12C5A60S2 microcontroller 2020 (30): 82~83.
[2] Qi H, Liu H .Design and Analysis of a Metasurface-based Wideband Wide-angle Scanning Phased Array[J]. 2023.
[3] Xinyu Di, Yujie Diao, Hongyu Zhu, Rushuang Zhou, Chao Xie. Design of an intelligent IoT desk lamp based on ESP32. Forestry Machinery and Woodworking Equipment. Forestry Machinery & Woodworking Equipment, 2023.
[4] Ting Zheng, Yin Peng, Yang Yang. Design of a multi-functional intelligent desk lamp based on a single-chip microcomputer, 2020 (17): 93~94, 98.
[5] Yuchen Zhang, Hua Wu, Biao Shang, et al. Design of Intelligent Voice-controlled Table Lamp Based on Arduino. Electronic Technology, 2021, 50(11): 18-19.
[6] Xiaoyan Wang. Design and research of an intelligent modular socket based on ESP32. China Equipment Engineering, 2021(24): 26-27.
[7] Lian Y, Wu D, Ji Z. STM32-Based Intelligent Desk Lamp Design and Implementation[J].Open Access Library Journal, 2021.DOI:10.4236/oalib.1107754.
[8] Yu Deng. Design of an Intelligent Desk Lamp Based on Single Chip Microcomputer, 2018(12): 9-10, 18.
[9] Liqi Liu. Design of intelligent LED desk lamp based on single-chip microcomputer. Light Industry Science and Technology, 2019, 35(1): 32-33.
[10] Cong Wang and Xinfeng Chang. Design and Implementation of an Intelligent Desk Lamp Based on 51 Single Chip Microcomputer. Internet of Things Technology, 2022
[11] Shulun Liu, Fukun Zhou, Shengcai Wu. Design and implementation of intelligent water-saving irrigation system based on LoRa IoT. Northern Horticulture, 2021, 45(6): 167-171.
[12] Wang M, Yao J, Westland J .A reliable location design of unmanned vending machines based on customer satisfaction[J]. 2023.
[13] Hui Zhao. Design of Multi-Functional Eye-Caring Desk Lamp Based on Single Chip Microcomputer. Electronic Technology and Software Engineering, 2018, 7(22): 239.
[14] Guofa Guo, Meng Xu, Kaisheng Zhang. Design of an intelligent water-saving irrigation system based on ZigBee wireless sensor network. Journal of Jiangsu Agricultural Sciences, 2015, 43(11): 513-518.
[15] Li Liu. Research and Design of Intelligent Lighting Control System. Chongqing: Southwest University of Science and Technology. Please note that the name format should be last name followed by first name in English, 2017.
[16] Vellidis G, Tucker M, Perry C, et al. A real-time wireless smart sensor array for scheduling irrigation. Computers & electronics in agriculture, 2008, 61(1): 44-50.
[17] Mingming Li. Study on Candidate Sub-1GHz Spectrum and Wireless Node Coverage Performance for IoT. China Radio Science, 2015, 26(8): 37-39.