# Research and design of a dimming control system based on STM32

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**Abstract.** The dimming control system with high efficiency and energy saving, simple and convenient operation is of great significance to daily life and industrial production. This paper we uses STM32 as the control core, designs a dimming control system based on PWM dimming mode and Bluetooth to send control commands. The experimental results show that the system can realize the smooth adjustment of the brightness of the four LEDs remotely.

**Key words:** STM32;Light-emitting-diodes(LEDs);Pulse width modulation(PWM);

## 1 Introduction

With the rapid development of LED lighting technology, people's demand for professional lighting is also increasing[1]. Compared with traditional lighting sources with single function, high energy consumption, nonlinear dimming and other shortcomings, LED has the advantages of high photoelectric conversion efficiency, low energy consumption, long life, fast response, etc. And LED is easy to combine with loT technology, which can better meet people's lighting needs[2]. At present, the common LED dimming technologies include analog dimming, PWM dimming and SCR dimming[3].Combined with the rapid response characteristics of LED, this paper uses PWM dimming technology to design a LED dimming control system based on STM32, and uses Bluetooth communication to realize the remote brightness control of LED.

EAI GreeNets 2021, June 06-07, Dalian, People's Republic of China

DOI 10.4108/eai.6-6-2021.2307129

## 2 Principle of PWM dimming

Pulse width modulation dimming(PWM dimming) is a method to control analog circuit by digital output of microprocessor. A series of pulse waves with different period and relative amplitude are used to replace the required waveform[4]. The luminous intensity of the LED is proportional to the current flowing through it, so the brightness of the LED can be adjusted by controlling the current. Combined with the fast response characteristics of LED, PWM dimming is used to make the switch circuit switch LED quickly at a certain frequency, that is to change the average current flowing through the LED to realize the switch and brightness adjustment of LED. In order to avoid the influence of light flicker on the human eye, the switch frequency should be set high enough that the human eye can’t recognize(generally greater than 100Hz)[5-6].

The basic principle of PWM dimming is shown in Figure 1. The pulse counter TIMx_CNT is set to count up, and the value of the auto reload register TIMx_ARR is ARR.As the clock source keeps counting, the value CNT of the pulse counter TIMx_CNT will be compared with the present value CCRx of the compare register TIMx_CCRx. When CNT>CCRx, output high electrical level(or low electrical level), otherwise output electrical low level(or high electrical level). Changing the value of CCRx can change the duty cycle of output PWM, and change the value of ARR can change the period of output PWM. The Timer period is ARR, and the duty cycle of the output PWM wave is $\frac{CCRx}{ARR+1}$.

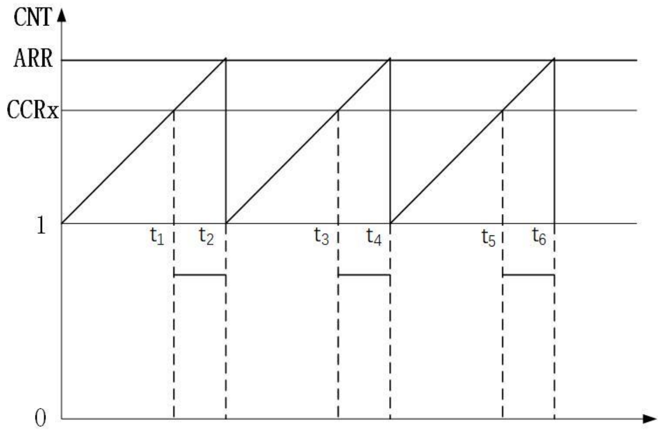


**Fig.1.** The operating principle of PWM

## 3 Overall design of dimming system

This paper selects STM32F103VET6 as the main control chip, which is mainly composed of Bluetooth module, LED drive module, power module and LED load, etc. The LED dimming control system is shown in Figure 2.Send control commands to the Bluetooth module through the mobile phone. The Bluetooth module communicates with STM32 microcontroller through serial port, control STM32 to output PWM waves with different duty ratio, and then outputs PWM waves to LED driver circuit to realize adjustment of LEDs' brightness remotely.

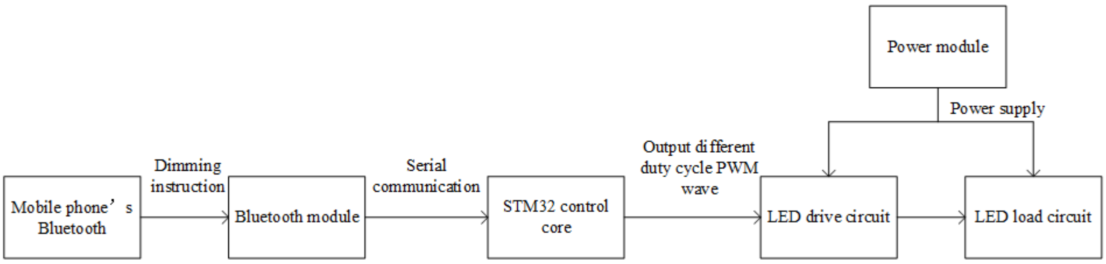


**Fig.2.** System overall design block diagram

## 4 The hardware design of dimming system

### 4.1 Main control module and peripheral circuit

In this paper, STM32F103VET6 single chip microcomputer is selected as control core. The peripheral circuit mainly includes reset circuit, crystal oscillator circuit, power supply circuit, etc. The reset circuit makes the whole system return to the initial state, the crystal oscillator circuit provides accurate clock signal for the dimming system, and the power supply circuit supplies power for the whole system.

The reset circuit is made up of 10K resistance and $0.1\mu F$ electric capacity, the circuit is shown in Figure 3. At the moment the system is powered on, the voltage across the capacitor cannot change suddenly. At this time, the input voltage to the NRST pin is low and the system is reset. Then the power-on voltage $V_{cc}$ charge the capacitor through the resistor R, and the voltage across the capacitor continues to rise. At this time, the high voltage level is input to the NRST pin, and the system works normally.

After pressing the reset button RESET, the power-on voltage $V_{cc}$, the resistance R, and the reset button RESET form a complete loop. The capacitor is short-circuited. At this time, the capacitor begins to discharge, and the voltage across the capacitor continues to decrease. The input voltage to the NRST pin is low and system reset.

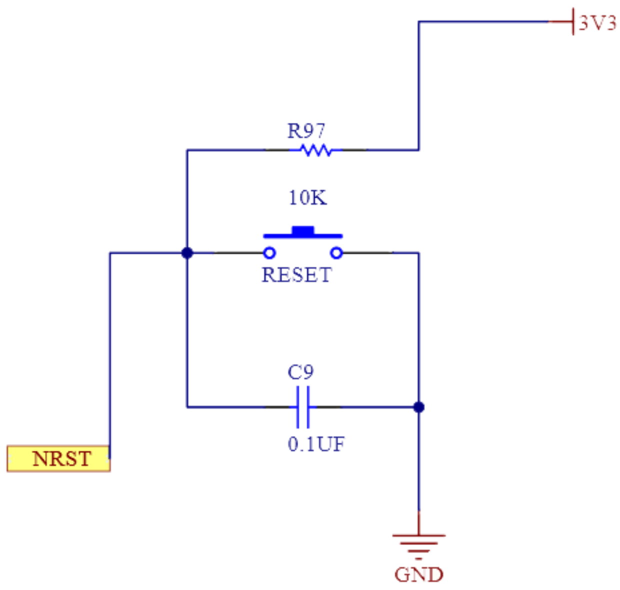


**Fig.3.** Reset circuit

STM32 mainly has two oscillation modes, namely HIS(internal high-speed clock) and HSE(external high-speed clock). In order to improve the clock accuracy, HSE is selected as the main clock source. Figure 4 shows the crystal oscillator circuit. The crystal oscillator selects an 8MHz HC-48SMD. The selection of $C_1$ and $C_2$ must be compatible with the circuit. The numerical relationship between $C_1$ and $C_2$ is shown in the following expression.

$$C_L - C_S = \frac{C_1 - C_2}{C_1 \cdot C_2} \tag{1}$$

$C_L$ represents the load capacitance, $C_S$ represents the parasitic capacitance between the two pins of the transistor[7], the input capacitance of the STM32 crystal oscillator is 5 $pF$, and the parasitic capacitance of the PCB trace is between 3~5 $pF$, so $C_L = 20pF$, $C_S = 9pF$. Normally, take $C_1$=$C_2$ and substitute the above formula to get $C_1$=$C_2 = 22pF$. To ensure normal start-up, the transconductance of the microcontroller $g_m$ is required to be much large than transconductance of the crystal oscillator $g_{mcrit}$. Generally, it’s required to be more than five times, and $g_{mcrit}$ is calculated by the following expression.

$$g_{mcrit} = 4 \cdot ESR \cdot (2\pi F)^2 \cdot (C_0 + C_L)^2 \tag{2}$$

ESR is the equivalent series resistance of the crystal oscillator, $F$ is the oscillation frequency of the crystal oscillator, $C_0$ is the parasitic capacitance between the two pins, and $C_L$ is the load capacitance[8]. According to the actual choice of single-chip microcomputer and crystal oscillator, substitute relevant data into the above formula to calculated $g_m$=25mA/V, $g_{mcrit} = 0.5894\text{mA/V}$, and $\frac{g_m}{g_{mcrit}} \doteq 42 \gg 5$. Therefore, choosing $C_1 = C_2 = 22pF$ can meet the starting vibration requirements.

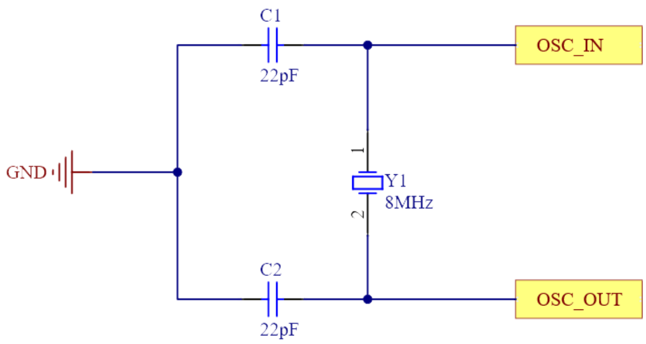


**Fig.4.** Crystal oscillator circuit

### 4.2 Bluetooth module and LED driver circuit

The Bluetooth module chooses ATK-HC05, this chip is mainstream Bluetooth chip which support Bluetooth V2.0 protocol standard CSR, the data transmission speed is within the range of 2M/s, and it's connected to the outside through 6 pin headers with a pitch of 2.54mm and the serial port module power supply voltage 3.3v, working current is about 40mA[9]. The module comes with a blue LED indicator. After it is successfully powered on, the LED flashes quickly to indicate that it is in the pairable state. After successful pairing, the LED double flashes. The HC-05 Bluetooth module can enter the AT state and communicate with the PC through the serial port. The initial properties of the Bluetooth can be set by inputting AT commands, including the device name, connection password, baud rate, master-slave mode, etc. The HC-05 Bluetooth module is connected to the microcontroller through four pins. RXD and TXD are respectively connected to the TXD and RXD pins on the microcontroller, namely the PA2 and PA3 pins. $V_{CC}$ and GND are connected to the power and ground respectively. The connection circuit is shown in Figure 5.

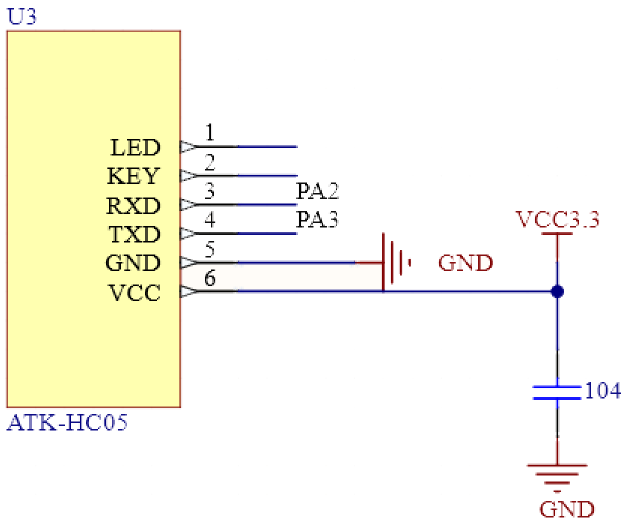


**Fig.5.** Bluetooth module connection circuit

The LED drive circuit uses the XL4001 module, which is a 150KHz fixed frequency step-down pulse width modulation DC/DC converter with a wide input voltage range of 4.5V~40V and a load driving capacity of 2A. It has good load capacity and only a small amount of external components is needed.

## 5 The software design of dimming system

This design program is written by Keil MDK programming software, and the computer language used for programming is C language. The whole process of program design is to initialize the system clock, GPIO port and serial port, etc. Then run to the main function, which is the concrete realization of the Bluetooth control function. First judge whether the Bluetooth data transmission is completed according to the status receiving flag n, then judge the transmitted data, increase or decrease the PWM duty cycle of the corresponding output channel according to the preset setting and return the value at the same time. This program realizes the regulation of the duty cycle of the four-way output PWM, and the main program flowchart is shown in Figure 6.

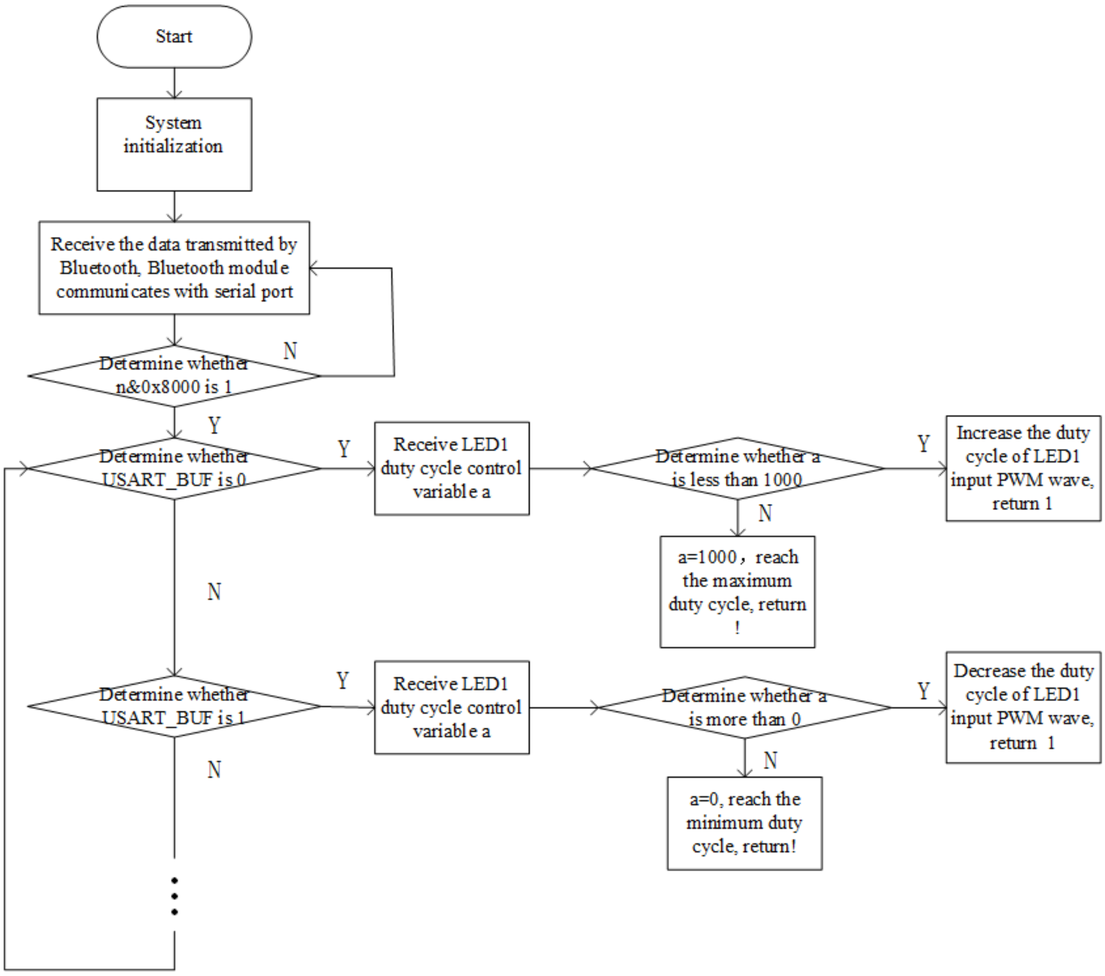


**Fig.6.** Main program flow chart

Choose Timer 3 and Timer 4 to output PWM wave, and set the frequency to 1KHz. The output ports are respectively set to PA6, PA7, PB6, PB7, respectively connected to the PWM input of the LED driver module, the initial PWM duty cycle of each output port is set to 0, and the frequency is 2KHz. Enable serial port 2 and complete the connection between the Bluetooth module and the microcontroller. PA2 and PA3 are the transmit-receive pins connected to the Bluetooth module, the baud rate of serial port 2 is set to 9600bps, and the interrupt processing function of the serial port is used to store the data transmitted by Bluetooth, Configuration functions are as follow:

TIM_Config();//Output PWM wave timer configuration, output frequency is set to 2KHz

PWM_Config();//Output PWM wave configuration, set its output mode, output comparison polarity, etc.

NVIC_PWM2_Config();//Timer 4 interrupt configuration function

LED_Config();//Configure four PWM wave output pins, set their output mode, pin rate, etc.

NVIC_Config();//Serial port 2 interrupt configuration function

USART_Config();//Serial port 2 configuration function, set its transceiver pin, transceiver mode, baud rate, etc.

void USART2_IRQHandler(void)// Serial port 2 interrupt service function, store data transmitted by Bluetooth

void TIM3_IRQHandler(void)// Timer 3 interrupt service function

void TIM3_IRQHandler(void)// Timer 4 interrupt service function

The main program judges the data transmitted by Bluetooth through the while(1) loop, and uses the status receiving flag n to judge whether the data transmission is completed. For the output PWM wave of channel 1, send a value of 0, after the Bluetooth module successfully receives the data through the serial port, the data is stored in the array USART_BUF[], the output PWM wave duty cycle increases by 1%, and the value 1 will be return. When increased to100%, continue to send the value 0, its duty cycle remains unchanged and returns !, at this time, the duty cycle has been adjusted to the maximum. Control program are as follow:

```
if(USART_BUF[0]== '0')
{
  if(a<1000)
  {
    a = a+10;
    TIM3->CCR1=a;
  USART_SendData(USART2,0x31);// Successful execution of the operation, return value 1
}
```

```
        if(a>=1000)
        {
          a=1000;
          TIM3->CCR1=a;
        USART_SendData(USART2,0x21);// Increase the duty cycle to the maximum, return !
        }
    }
```

Send a value of 1, after the Bluetooth module successfully receives the data through the serial port, the data is stored in the array USART_BUF[], the output PWM wave duty cycle will decrease by 1% and the value 1 will be return. When decreased to 0%, continue to send the value 1, its duty cycle remains unchanged and return !, at this time, the duty cycle has been adjusted to the minimum. Control program are as follow:

```
        if(USART_BUF[0]== '1')
        {
          if(a>0)
          {
            a=a-10;
            TIM3->CCR1=a;
            USART_SendData(USART2,0x31);// Successful execution of the operation, return value 1
          }
          if(a<=0)
          {
            a=0;
            TIM3->CCR1=a;
            USART_SendData(USART2,0x21);//Decrease the duty cycle to the minimum, return !
```

```
        }
    }
```

The other three PWM output procedures are similar. Writing the program in this way is easy to control the duty cycle of each output PWM wave, and we can change the step length of each increase or decrease of the duty cycle to achieve more convenient and precise brightness control of each LED, and the return value can be very intuitive shows whether the data transmitted by Bluetooth is successfully received or whether the duty cycle has been adjusted to the upper and lower limits.

## 6 Experiment and result analysis

According to the above software and hardware design, the dimming control system is completed as shown in Figure 7.

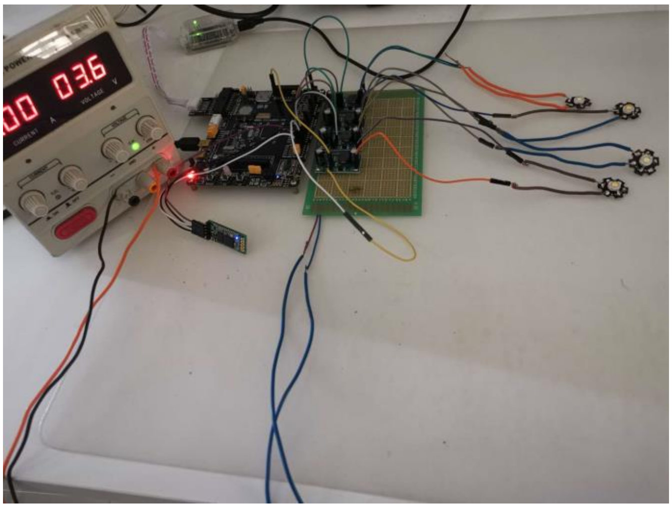

**Fig.7.** Dimming control system

Perform dimming experiments with different duty cycles on the dimming control system. In order to ensure the stability of the system, the power supply outputs 3.6V and the LED brightness can be kept stable. The mobile phone is connected to the Bluetooth module, and the blue indicator light of the Bluetooth module flashes double after successful pairing. Through the Bluetooth serial port assistant of the mobile phone, set the duty cycle of the four output PWM waves to 10%, 40%, 70% and 100% respectively, and observe with an oscilloscope. The output waveforms are shown in Figure 8 and Figure 9. The dimming effect of each LED at different duty cycles is shown in Figure 10. The four LEDs input PWM wave duty cycles from top to bottom are 10%, 40%, 70% and 100%.

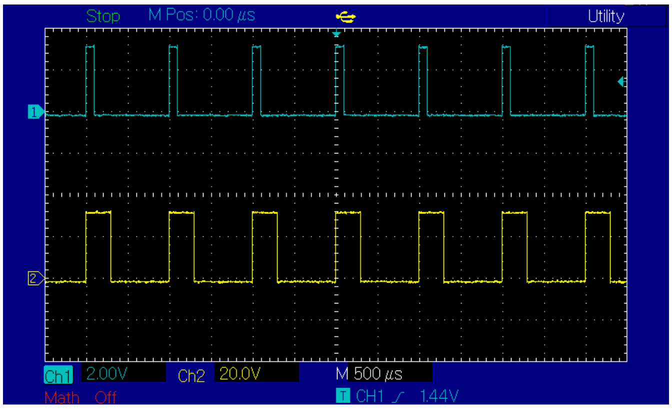


**Fig.8.** Output PWM waveforms with duty ratios of 10% and 40%

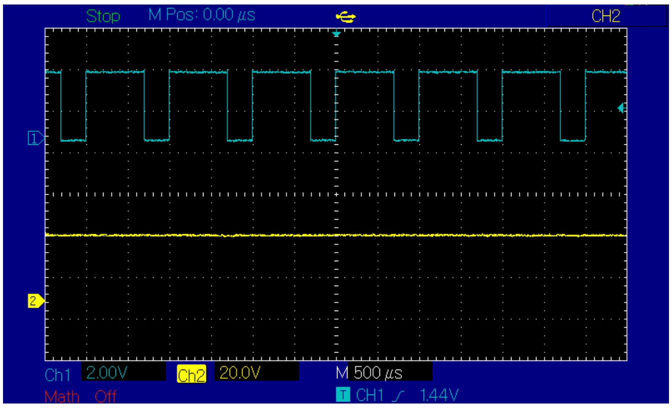


**Fig.9.** Output PWM waveforms with duty ratios of 70% and 100%

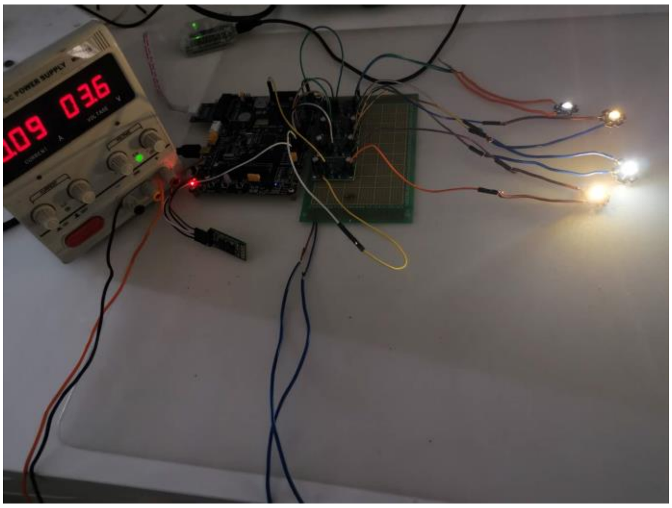

**Fig.10.** The dimming effect of each LED under PWM wave input with different duty cycles

From the above experiments, the LED dimming system controls the output of a stable voltage and current, and smooth brightness adjustment of the four LEDs can be achieved through the Bluetooth control of the mobile phone, which meets the design requirements of the dimming system.

## 7 Conclusion

With the deep integration of LED lighting technology and Internet of Things technology, its applications in the lighting field are becoming wider and wider, and at the same time it can better meet people's lighting requirements. This paper selects STM32F103VET6 as the main control chip, combined with Bluetooth wireless communication and achieve brightness control of the four LEDs remotely. It can be seen from the experimental results that the system can smoothly adjust the brightness of the four LEDs to meet the expected requirements. The system has simple structure and convenient control, which provides a reference for the research and design of LED wireless control system.

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