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Voice Transmission System based on Visible Light Communication Technology

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Abstract

Visible light communication technology is the transmission of information by using high-frequency optical wave signals, such as fluorescent lamps or light-emitting diodes (LEDs), that are indistinguishable to the naked eye. With this technology, all LED lights can become the base station of Internet. In this paper, the audio data is transmitted in real time by means of combination of software and hardware, with visible light as the information carrier and air as the medium. In this paper, the visible light communication technology of PWM modulation technology is used to realize the voice signal transmission, and the circuit is designed and simulated by using AD and Multisim etc. software. After testing, the effective communication distance of the system is up to 1.1 meters, and the voice signal is transmitted without distortion based on visible light communication technology.

Keywords

Visible Light Communication Technology; LED; PWM Modulation; Voice Transmission.

1. Introduction

Visible light communication technology is an emerging optical communication technology, which may be applied in future 6G communication. The data is transmitted in free space with the light wave from the lighting source as the carrier, and the functions of lighting and communication are taken into account. And in the world, led as a lighting device has been widely used, only need to add a microchip in the LED lamp, the device can realize the function of lighting and communication at the same time.

Therefore, the visible light communication system has a broad development prospect in indoor wireless communication, which can not only form complementary advantages with WiFi technology, but also become an independent communication mode. This paper mainly realizes and studies the voice transmission system based on visible light communication technology.

2. System design scheme

The overall block diagram of a voice transmission system based on visible light communication is shown in Figure 1.

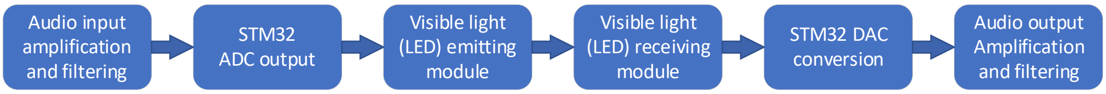

Figure 1. Overall block diagram of voice transmission system

The visible light voice communication system is mainly divided into two parts: the transmitter and the receiver (Fig. 1). The system uses STM32F103VCT6 microcontroller as the main controller and adopts PWM modulation technology. The transmitter sends the input voice signal to the amplifying

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and filtering circuit, and finally to the visible light transmitting module and transmits the voice signal to the air; The receiver can recover the original information through receiving, power amplification and demodulation of the transmitted light, so as to complete the transmission of voice data [1].

3. System hardware design

The hardware circuit of this system mainly consists of light-emitting module, light-receiving module, voice signal input module, voice signal power amplifier output module.

3.1 Circuit Design of Visible Light Emission Module

The schematic diagram of the circuit design of the visible light emitting module is shown in Figure 2. Pin 3 of P1 port is the signal output port, which connects to the PB0 port of STM32. The current output by I/O port of STM32 controller is very limited, which can not meet the needs of high power emission of light emitting diode. Therefore, it is necessary to design an LED driving circuit, which is mainly composed of common emitter amplification circuit. The signal is input by base and emitter of the triode, and output from collector and emitter of the triode[2].

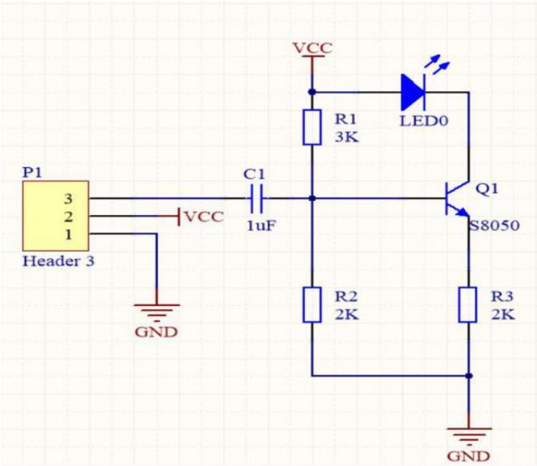

Figure 2. Schematic diagram of visible light emitting module

The logic level of the whole visible light emitting circuit is consistent with that of the I/O port of STM32 controller. If the I/O output is 1, the LED starts to work and the I/O output is 0, the LED stops working. The PCB of the visible light emitting module is shown in Fig. 3. The whole module is powered by 5V.

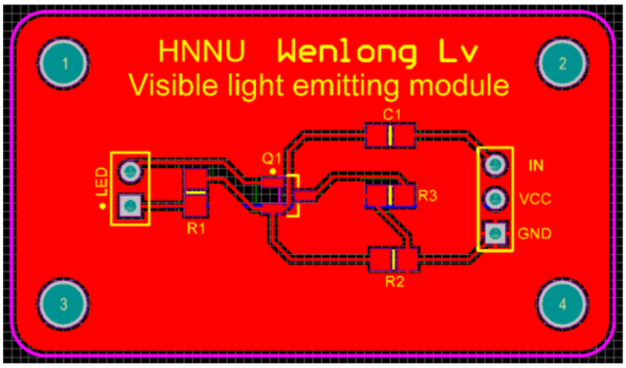

Figure 3. The PCB visible light emitting module

In Figure 3, the IN pin is the module interface, which converts the received electrical signal into visible light signal and sends it to the air. In this system, the IN pin is controlled by STM32, which directly controls the LED on and off [3].

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3.2 Circuit design of optical receiving module

The acceptable power supply voltage of the visible light emitting module is 5V, which can amplify, compare and output the visible light signal received by photodiode. Because there are many signal processing circuits integrated in the module, the peripheral circuit design of the module is relatively simple, with high integration and strong reliability. The overall circuit schematic diagram of the visible light receiving module is shown in Fig.4.

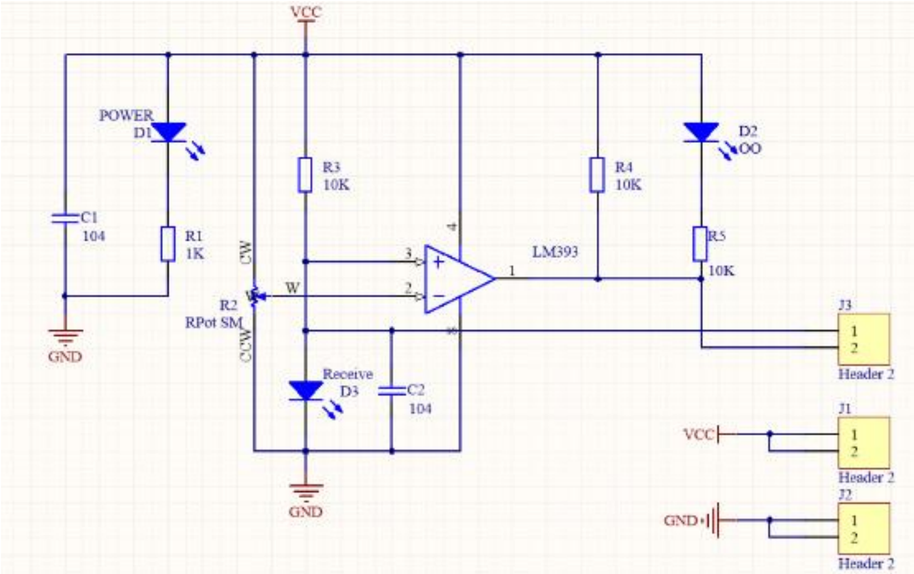

Figure 4. Schematic diagram of visible light receiving module

The PCB design of visible light receiving module is shown in Figure 5. In this design, two LEDs are specially added, named PWR and Rx respectively. When the PWR light is on, it represents the normal power supply of the power supply, and RX light on means visible light data received. The OUT port in Figure 5 is used to output the signal after photoelectric conversion, which is composed of left port and right port. The 2-pin of the OUT port outputs digital signal, and 1-pin of the OUT port output s analog signal. In this system, the OUT port is directly connected to the timer capture I/O port of STM32 [4].

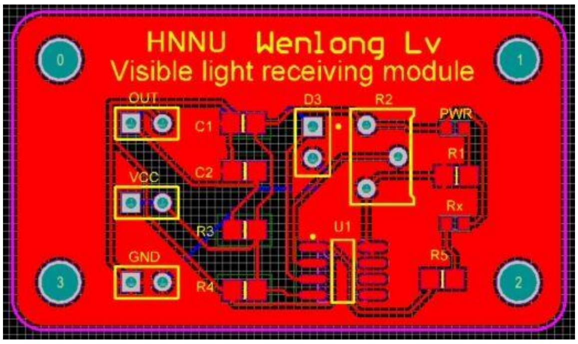

Figure 5. The PCB of visible light receiving module

3.3 Circuit design of voice input module

The voice input module is mainly composed of pre-amplifier circuit, low-pass filter circuit and high pass filter circuit. The pre-amplifier can automatically adjust the amplification factor according to the volume of the input voice signal [5]. The low-pass filter circuit and the high pass filter circuit constitute the band-pass filter circuit, which can filter out the noise signal whose frequency is less than 300Hz and more than 3400Hz. The main circuit diagram is shown in Fig.6 -Fig8.

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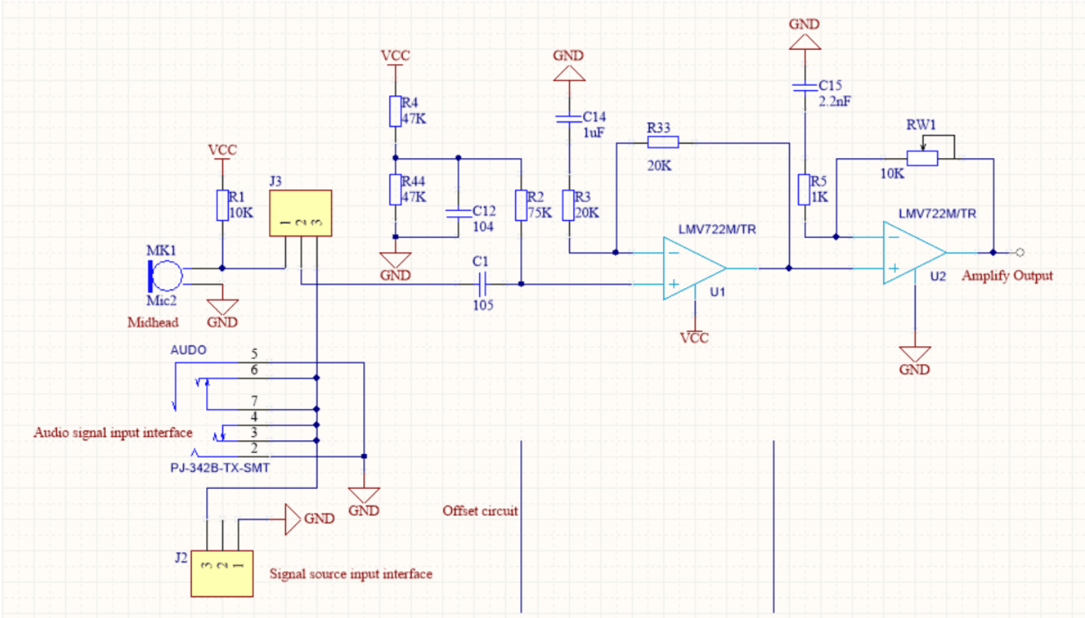

Figure 6. Pre-amplifier circuit diagram

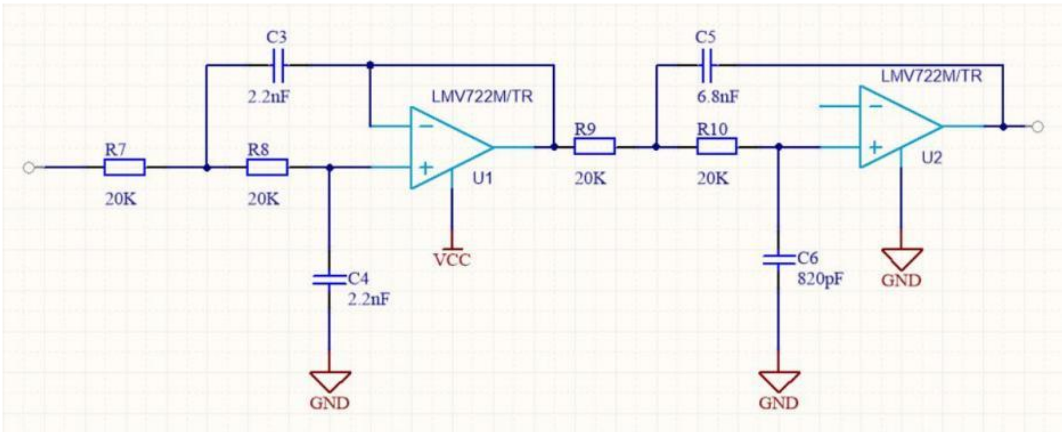

Figure 7. Circuit diagram of low pass filter

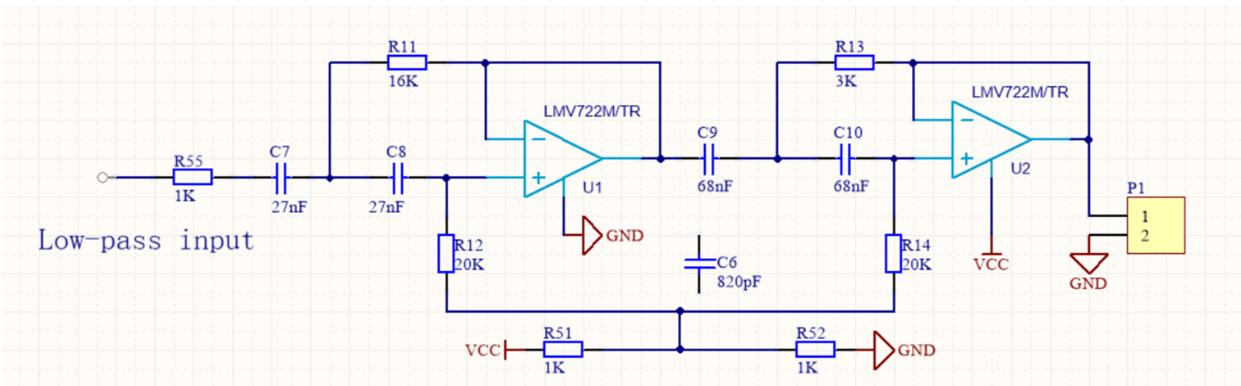

Figure 8. Circuit diagram of high pass filter

3.4 Circuit design of voice output module

The voice output module uses the internal DAC of STM32 to output the audio signal. The voice signal enters the power amplifier module, and then directly drives the loudspeaker , and the original analog voice signal can be obtained[6].

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In this system, due to the poor driving ability of STM32 I/O port, it is necessary to add a power amplifier to amplify the analog voice signal, so that the original voice signal can be heard in the loudspeaker [7]. Because of the DAC output of STM32 will also have certain noise, which will lead to the final output voice very noisy, so a band-pass filter is also needed in the voice signal power amplifier module to filter the noise signal.

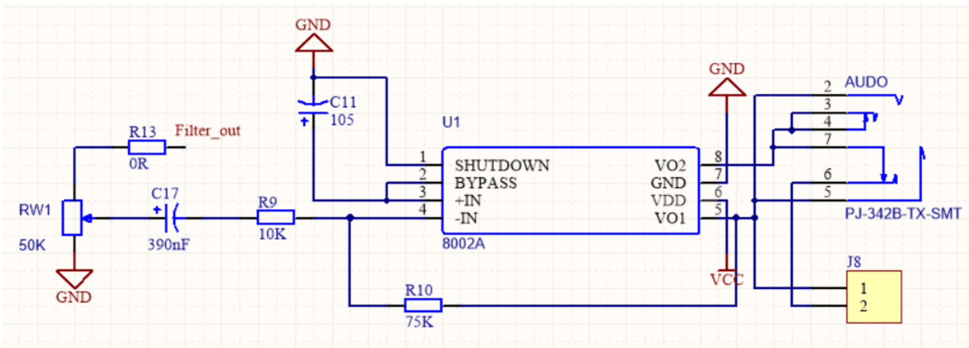

Figure 9. Power amplifier output circuit diagram

The power amplifier circuit adopts a dual-channel monolithic integrated power amplifier chip 8002. 8002 is a kind of bridge audio amplifier. The total harmonic distortion is less than 1%. It needs few peripheral devices and can provide high-quality output power. It is often used in audio, earphone, radio and other circuits.

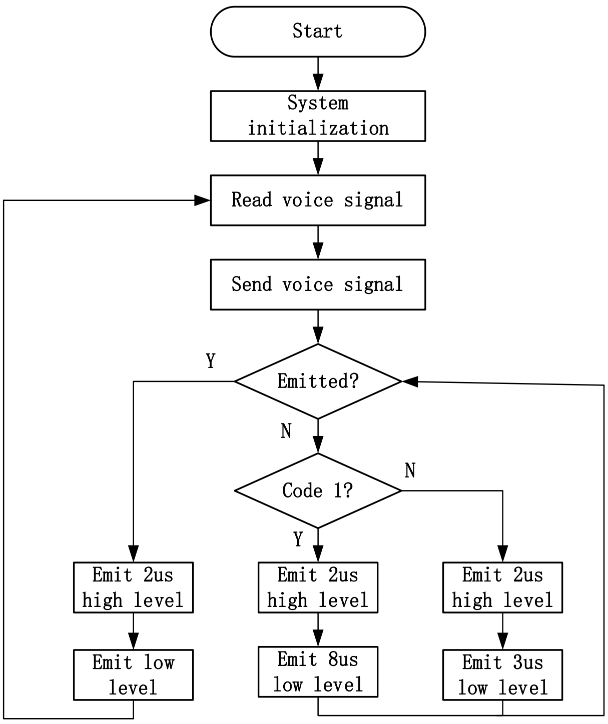

Figure 10. Total program flow chart of transmitter

4. System software design

4.1 Program Design of transmitter

The total procedure of the transmitter is shown in Figure 10. MCU is powered by USB. After power on, MCU first executes the initialization program of each hardware module. First, the initialization

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program of OLED is executed and a section of OLED startup animation is displayed. Then turn on the ADC function and set the frequency to 8kHz. After each sampling, the data is sent once, and after the transmission, the next sampling is continued, so the cycle goes on. In this program, AD data acquisition and encoding output sub-functions are executed in the timer interrupt to improve the efficiency of MCU.

4.2 Program Design of Receiver

The total program flow chart of STM32 at the receiving end is shown in Figure 11. After power on, MCU first executes the initialization program of each hardware module[9]. Then turn on the capture function of STM32 timer, and connect the OUT port of the visible light receiving module to the capture pin. After STM32 successfully captures the signal, it directly converts the digital voice signal to the analog voice signal through DAC and outputs it. The code capture and DAC output sub-functions are also executed in timer interrupt [10].

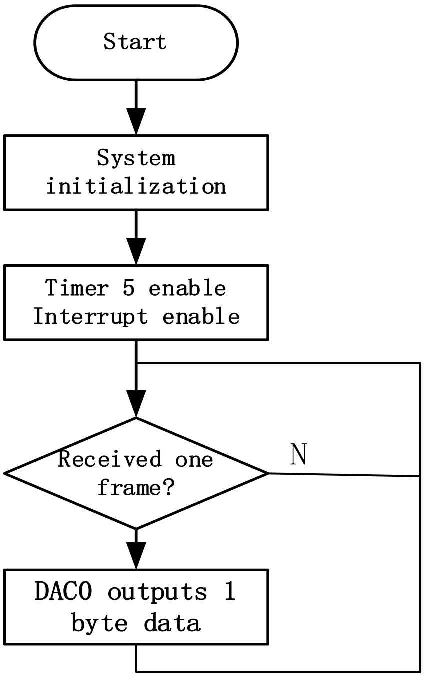

Figure 11. Total program flow chart of receiver

5. System integration and test

5.1 System integration

In order to minimize the jumper connection, unify the power supply, improve the stability and reliability of the system, and facilitate the module installation and testing, the whole system is integrated into two modules, namely the transmitter motherboard and the receiver motherboard (Fig12 and Fig.13). Using Altium designer software, draw these two PCB boards and send them to the factory for processing and manufacture.

5.2 System Test

5.2.1 Functional test

Connect the external speaker to the output port of the power amplifier, and keep the distance between the transmitter and the receiver at 0 meters and the angle at 0 degrees. After the power is turned on, the OLED will first display a simple power on animation, and then the voice signal will be transmitted, as shown in Fig 14. Next, the oscilloscope is used to check the received signal to verify whether the system can complete the transmission of voice signal.

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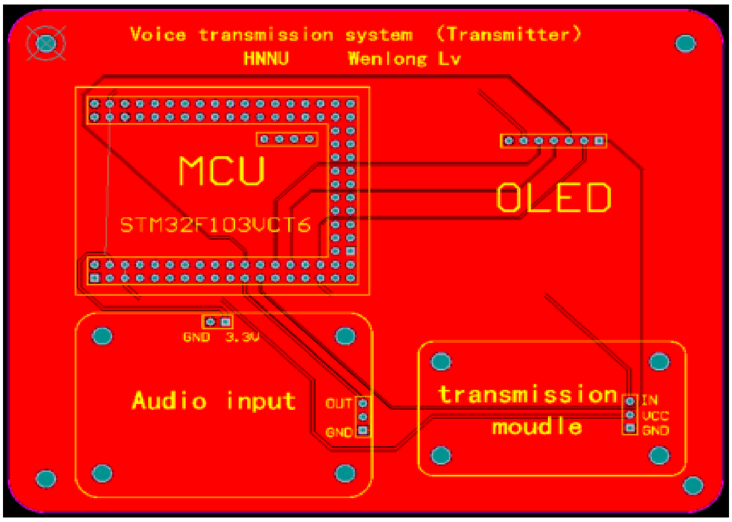

Figure 12. Transmitter motherboard

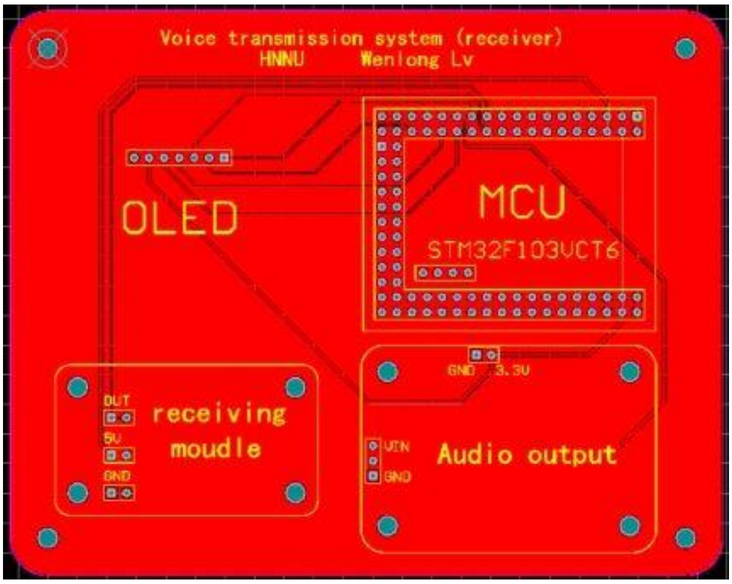

Figure 13. Receiver motherboard

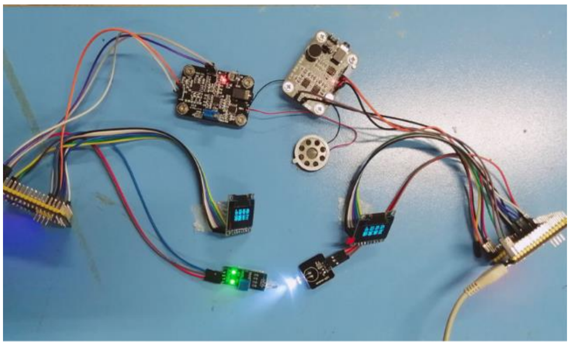

Figure 14. Voice transmission system experimental platform

After testing, the microphone input and audio input work normally without obvious distortion. Use the two channels of the oscilloscope to test the waveforms of the transmitting module and the receiving module respectively, as shown in Figure 15. In the figure, the Yellow waveform is the visible light transmitting module waveform, and the blue waveform is the visible light receiving module waveform.

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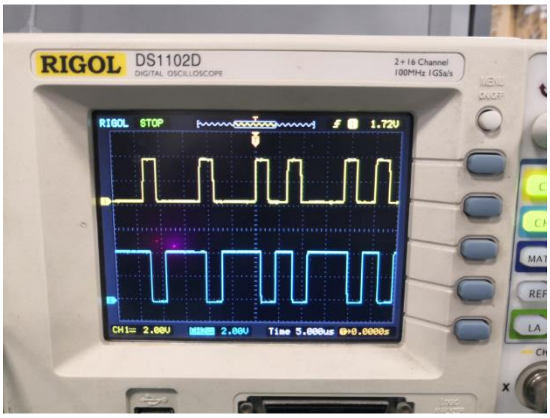

Figure 15. Waveform diagram of visible light transmitting and receiving module

5.2.2 Transmission test

when the transmitting and receiving modules are aligned and there is no debris or other light interference, if the transmission distance reaches 1.2 meters, the sound will be distorted; if the distance exceeds 1.5m, the signal is finally broken, as shown in Table 1.

Table 1. Distance test

	0.8M	0.9M	1.0M	1.1M	1.2M	1.3M	1.4M	1.5M
Distortion	×	×	×	×	√	√	√	√
Breaking	×	×	×	×	×	×	×	√

The distance between the transmitting and receiving modules is fixed at 0.15m, if the relative angle reaches 45°, the sound is distorted; if relative angle over 50°, the signal is finally broken, as shown in Table 2.

Table 2. Angle test

	30°	35°	40°	45°	50°	55°
Distortion	×	×	×	×	√	√
Breaking	×	×	×	×	×	√

Add an signal interruption alarm program in the system. When the signal is blocked or broken due to distance, angle and other problems, the system on the receiving board will light up a blue LED to indicate that the signal is lost and the system stops working.

6. Conclusion

The visible light voice transmission system uses STM32F103VCT6 as the controller, adopts PWM coding mode, and successfully meets the requirements of real-time digital transmission of voice signal. Through comparative experiments, the effective communication distance of the system can reach 1.1m. When the relative distance between the two modules is less than 0.15m and the effective transmission angle less than 45°, voice signal can be transmitted without distortion in the system.

Acknowledgments

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