

DESIGN OF INFRARED OPTICAL COMMUNICATION AND TEMPERATURE TRANSMISSION SYSTEM BASED ON OOK MODULATION

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Abstract: This paper designs an infrared optical communication system based on OOK modulation to realize synchronous transmission of voice signals and digital temperature signals as well as temperature display. The system consists of a transmitter, a relay forwarding node, and a receiver. The transmitter superimposes voice signals and OOK-modulated temperature signals and sends them through an infrared emission tube; the relay node amplifies and forwards the signals; the receiver demodulates and recovers voice and temperature information. The system features low power consumption, with a receiver noise of approximately 0.02 V and a relay power consumption of about 150 mW. Experiments show that the transmission is stable, making it suitable for low-power short-distance scenarios.

Keywords: Infrared optical communication; OOK modulation and demodulation; UART protocol

1 INTRODUCTION

With the development of communication technology, infrared optical communication has been widely used in short-distance wireless transmission due to its low cost, low power consumption, and privacy. Infrared communication realizes data transmission through the propagation of optical signals in free space, which is suitable for smart homes, electronic devices, wireless sensor networks, and other scenarios. However, its transmission distance is limited by line-of-sight conditions, and the system stability and anti-interference ability still need to be further optimized [1-2]. Existing studies have shown that infrared communication systems can achieve high security and energy efficiency ratio while meeting certain transmission rate and distance requirements, showing good engineering application prospects [3]. In such short-distance scenarios, the demand for synchronous transmission of voice interaction, ambient temperature, and other information is gradually increasing, requiring the system to achieve reliable transmission under low-power conditions.

For synchronous transmission of voice and temperature information, system schemes usually trade off between digital communication and analog communication. Digital schemes have strong anti-interference performance but occupy large frequency bands and are complex to implement; analog schemes have simpler structures and lower power consumption but are susceptible to interference. This paper selects an analog composite transmission method based on OOK modulation to balance implementation complexity and power consumption requirements. Among them, OOK modulation is widely used in wireless communication systems due to its simple implementation and low power consumption [4].

For the temperature link, temperature data can be transmitted directly via UART or composited with voice after OOK modulation. The former is simple to implement but has weak fault tolerance and is vulnerable to bit errors; the latter adds modulation and demodulation links but provides higher reliability. The relay design also has two paths: "demodulation-processing-retransmission" and "amplification and forwarding". The former has better performance but significantly increases power consumption and complexity. Therefore, this paper adopts a low-power amplification and forwarding structure to simplify the system and optimize energy consumption. Based on the above trade-offs, this paper implements an infrared optical communication and temperature transmission system for short-distance, low-power applications.

2 SYSTEM SCHEME ANALYSIS AND DESIGN

This system adopts an analog composite transmission scheme based on OOK modulation to realize synchronous transmission of voice and temperature information. At the transmitter, temperature UART data is OOK-modulated with a 50 kHz carrier wave and then analog-superimposed with voice signals to form a composite signal, which is sent through an infrared link. The relay node adopts a simplified "receive-amplify-forward" structure, which amplifies the received signal and forwards it directly to balance link extension and low power consumption. At the receiver, the composite signal is amplified, filtered, and demodulated. The voice channel suppresses carrier components through low-pass filtering to recover audio, and the temperature channel demodulates the OOK components to recover UART waveforms, which are sent to FPGA for decoding and drive LCD to complete temperature display [5].

The system structure is shown in Figure 1. After the composite signal is amplified and forwarded by the relay, it is split at the receiver to recover voice and temperature. The temperature channel adopts "band-pass filtering-full-wave

rectification-low-pass smoothing-threshold shaping" to recover UART levels, realizing reliable decoding and display of temperature data [6].

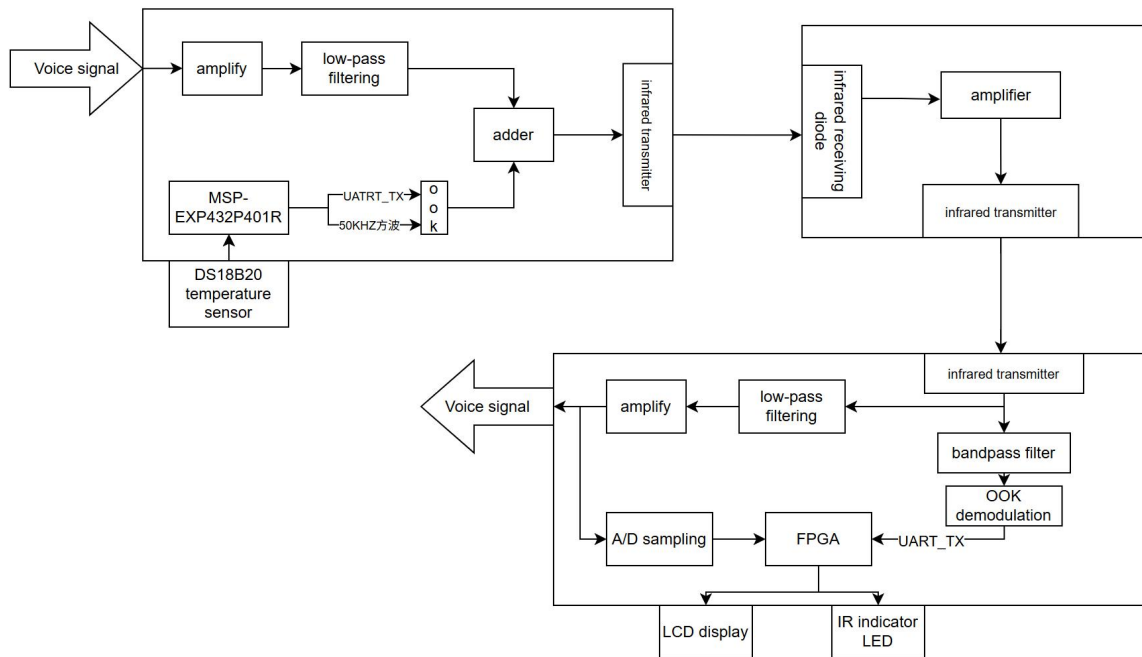


Figure 1 System Block Diagram

System block diagram is shown in Figure 1.

3 THEORETICAL ANALYSIS

3.1 Infrared Transmission Distance and Receiving Power

Signal transmission distance depends on transmission intensity, radiation angle, and receiving sensitivity. The relationship between illumination intensity and distance is:

$$E = \frac{I}{R^2} \tag{1}$$

where I is the illumination intensity and R is the distance between the transmitter and the receiver. The illumination intensity E determines the transmission power P_t of the emission tube. The receiving power P_r of the receiving tube is:

$$P_r = P_t \cdot \frac{A_{et}A_{er}}{(R\lambda)^2} \tag{2}$$

where λ is the wavelength of infrared light, A_{et} is the effective area of the emission aperture. The smaller the half-power angle of the emission tube, the larger A_{et} is. Under a certain transmission power, to ensure a 2 m communication distance, the receiving tube should be aligned with the main radiation direction of the emission tube to increase the effective receiving area [7].

3.2 Relay Power Consumption Analysis and Modulation-Demodulation Analysis

The receiver uses OPA656 and OPA828 to amplify signals, and the op-amp current is about 10 mA under low-frequency working conditions [8]. The transmitter amplifies current through a triode and reduces the static operating point, controlling the total current within 30 mA and power consumption at about 150 mW. The temperature link performs OOK modulation on the UART code stream, loading information by controlling the on-off of the carrier wave with a binary sequence. The receiver adopts non-coherent demodulation (envelope detection), and recovers the baseband UART signal through band-pass filtering, rectification/envelope detection, low-pass smoothing, and comparator shaping.

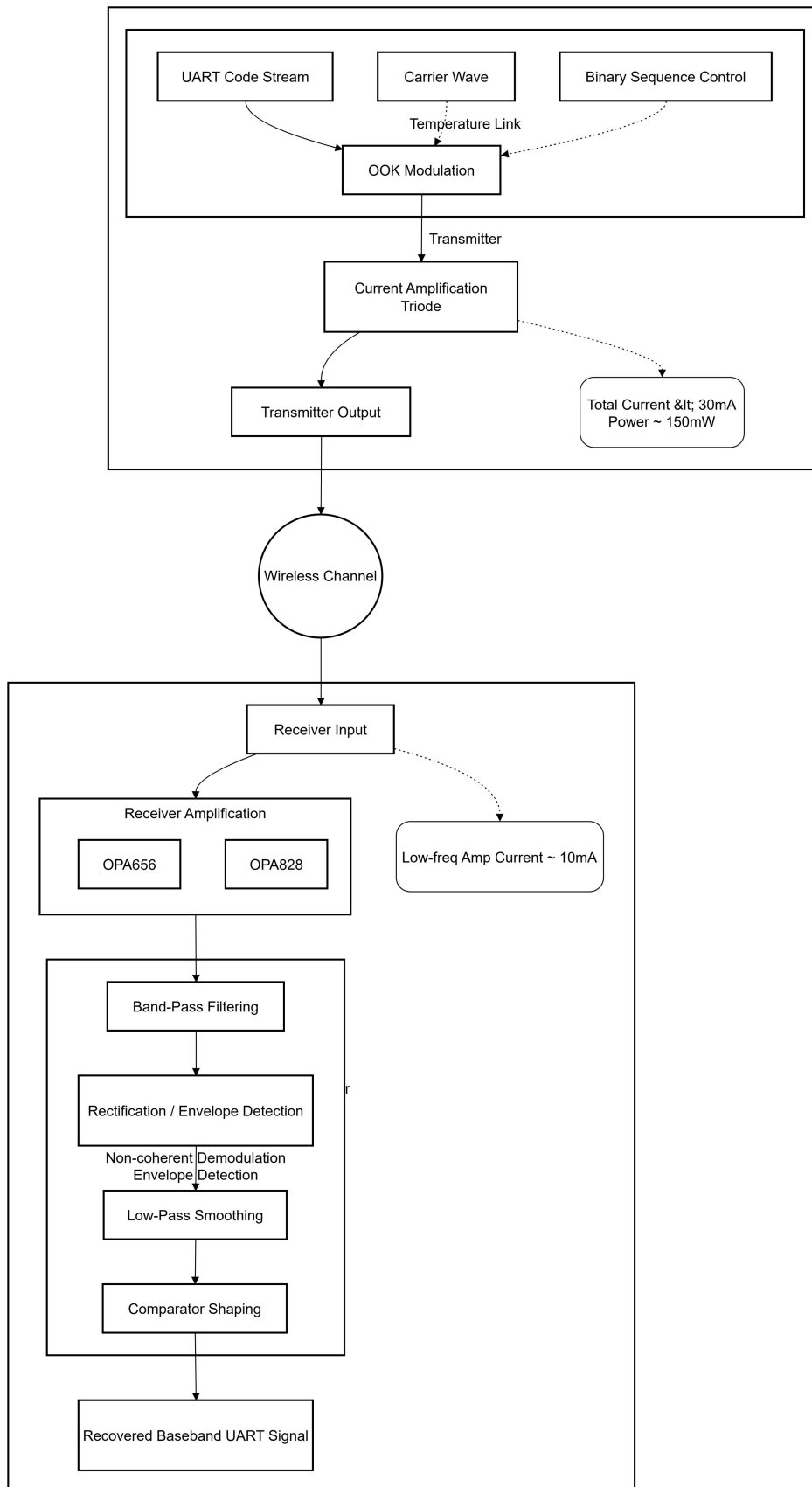


Figure 2 Hardware Architecture and Signal Processing Flow of the OOK Transceiver System

Hardware Architecture and Signal Processing Flow of the OOK Transceiver System is shown in Figure 2.

4 CIRCUIT AND PROGRAM DESIGN

4.1 Circuit Design

At the transmitter, the voice signal is input through an audio jack, amplified, filtered, and processed in a single power domain to form a unipolar signal. The digital temperature signal and 50 kHz carrier wave are OOK-modulated through an AND gate, then analog-superimposed with the voice signal to form a composite signal, which is sent to the infrared emission circuit. The relay node consists of infrared receiving and transmitting circuits. OPA656 converts the weak received current signal into a voltage signal, which is further amplified by OPA828, and then the transmitter is driven by a common-collector triode 9013 to realize amplification and forwarding. By reducing the static operating point of the triode, the relay power consumption is about 150 mW. Architecture of Infrared Audio and Temperature Data Relay System is shown in Figure 3.

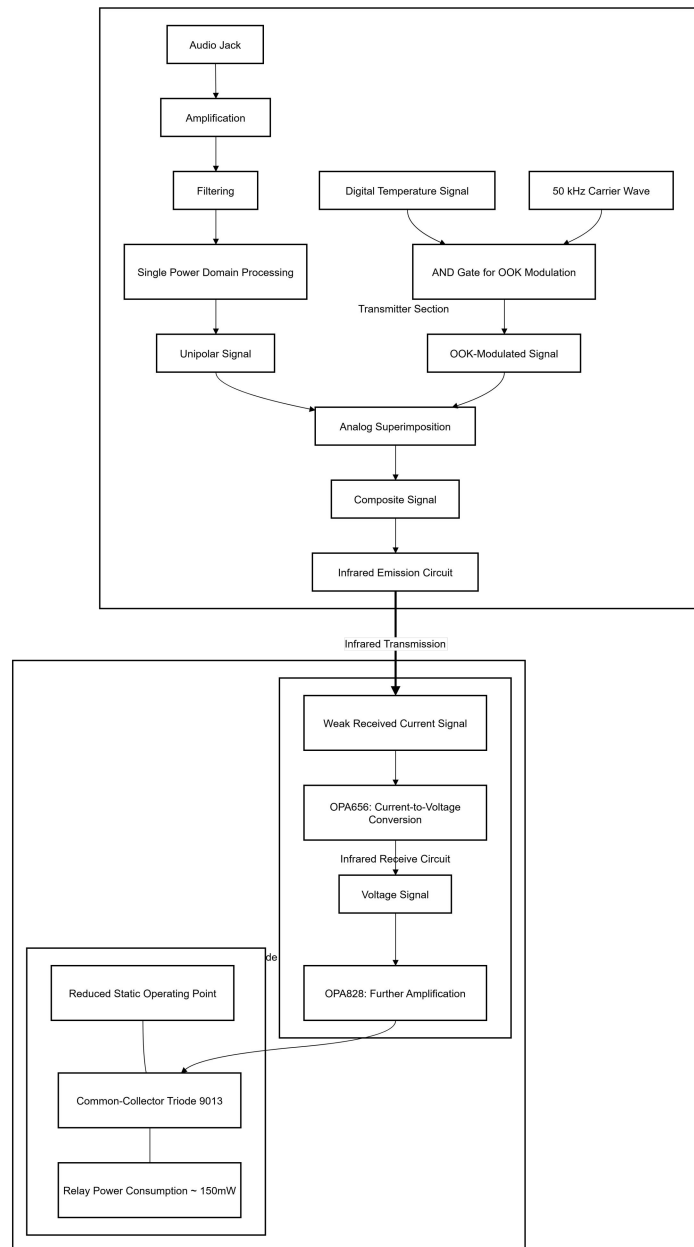


Figure 3 Architecture of Infrared Audio and Temperature Data Relay System

After amplifying the infrared signal at the receiver, the voice channel adopts a multi-stage low-pass filter with a cutoff frequency of about 6 kHz to suppress temperature carrier components and recover audio. The audio is then amplified by OPA1602 and driven by a TDA2822M power amplifier for output. The temperature channel adopts band-pass filtering to suppress noise and perform envelope recovery. The core circuit, a full-wave rectifier, uses the unidirectional conductivity of diodes and the charging and discharging of capacitors to realize full-wave rectification [8-10]. After rectification, low-pass smoothing filters out ripples, and finally, the comparator threshold shaping recovers stable square-wave UART levels, realizing reliable decoding and display of temperature data.

4.2 Software Program Design

The MSP-EXP432P401R collects temperature and outputs UART code streams to participate in composite transmission at the transmitter. The FPGA at the receiver decodes temperature data, drives the LCD display, and completes voice link indication at the same time.

5 TEST SCHEME AND TEST RESULTS

5.1 Test Scheme

Tests are carried out under a 2 m line-of-sight condition. The voice link is evaluated for distortion by music audition and 300–3400 Hz frequency sweeping; an 800 Hz tone is tested under an 8 Ω load, the output effective value is measured by changing the input amplitude, and the static noise voltage is measured with the input set to 0 V. For the temperature link, the ambient temperature near the temperature sensor is changed, and the error is evaluated by comparing the displayed value with the actual value. For relay power consumption test, a milliammeter is connected in series into the relay circuit to measure the working current, and the power consumption is calculated combined with the supply voltage.

5.2 Test Results and Data

5.2.1 Signal distortion test

A voice link transmission test is carried out under a 2 m line-of-sight condition, with the input changed to a sine tone signal between 300–3400 Hz. The results show that the audio signal is undistorted, and the waveform observed by an oscilloscope is stable as a whole.

5.2.2 Temperature transmission test

The ambient temperature around the temperature sensor is changed, and the displayed value is compared with the actual value. The experimental results show that the temperature data can be correctly recovered, with a maximum relative error of about 3.3%.

5.2.3 Receiver voltage test

Table 1 Receiver Voltage Test Table

Input Signal Voltage Amplitude / V	Input Signal Frequency / Hz	Receiver Voltage / V
0.1	800	0.438
0.05	800	0.226
0	800	0.023

Receiver voltage test table is shown in Table 1.

The results in Table 1 show that the receiver voltage changes as expected under different input voltage amplitudes.

5.2.4 Relay power consumption test

Table 2 Relay Power Consumption Test Table

Input Signal Voltage Amplitude / V	Receiver Voltage / V	Relay Power Consumption Current / mA	Relay Power Consumption / mW
0.1	0.438	300	150
0.05	0.226	295	147.5
0	0.023	290	145

Relay power consumption test table is shown in Table 2.

The results in Table 2 show that when the input signal voltage amplitude decreases, the power consumption of the relay node decreases accordingly, and the relay current and power consumption are within the expected values.

6 CONCLUSION

This paper implements an infrared optical communication and temperature transmission system based on OOK modulation, and uses an amplification and forwarding relay to extend the link. Experiments show that the system can stably transmit voice and temperature signals, meeting the requirements of low power consumption and accuracy. Overall, the system is suitable for short-distance low-power applications.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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