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Design of Intelligent Fire Extinguishing Vehicle Based on STM32

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Abstract

Aiming at the problems of high safety risks for personnel in fire rescue and the lagging response of traditional fire-fighting equipment, this paper designs an intelligent fire-extinguishing trolley control system with the STM32F103C8T6 microcontroller as the core. The system integrates a power supply circuit, motor drive circuit, multi-sensor detection modules (flame, temperature, smoke, obstacle avoidance) and a fire-extinguishing actuator to realize functions such as fire source positioning, automatic obstacle avoidance, sound and light alarm, and desiccant spraying for fire extinguishing. In terms of hardware selection, the L298N chip is used to drive the DC motor to realize the trolley's motion control; the DS18B20 sensor is used for temperature measurement, the AC4067 infrared sensor for flame detection, the MQ-2 sensor for smoke detection, and the E18-D80NK sensor for obstacle avoidance, ensuring the coordinated and stable operation of each module. Tests show that the trolley can quickly detect the fire source, accurately avoid obstacles, and start fire extinguishing within 10 seconds after locating the fire source, which can effectively improve the efficiency of initial fire handling and reduce the risk of casualties.

Keywords

Intelligent Fire-extinguishing Car; STM32F103C8T6; L298N; Multi-sensor Fusion.

1. Introduction

Fire is one of the major disasters threatening public safety. Traditional fire rescue relies on on-site operations by firefighters, and risks such as high temperatures, thick smoke, and building collapses significantly increase the probability of casualties among rescue personnel. With the development of embedded technology and sensor technology, intelligent fire-extinguishing equipment has become an important research direction in the field of fire protection. By realizing automatic control through a single-chip microcomputer, it can replace manual work in initial fire detection and suppression, which can greatly reduce rescue risks and improve disposal efficiency.

The intelligent fire-extinguishing trolley designed in this paper integrates multi-dimensional detection of flame, temperature and smoke, and has the functions of automatic tracking, fire source tracking and manual control. It can be applied to initial fire scenarios in small spaces such as homes, laboratories and warehouses. By optimizing hardware selection and software logic, the integrated function of "detection-positioning-obstacle avoidance-extinguishing-alarm" is realized, providing a feasible solution for the research and development of low-cost intelligent fire-fighting equipment.

2. System Scheme Design

The system is centered on STM32F103C8T6 and is divided into five major modules: a power module (providing 3.3V/5V/6V voltages), a detection module (flame + temperature + smoke +

obstacle avoidance), a drive module (L298N + DC motor), and an execution module (desiccant spraying + sound and light alarm).

Working logic:

• Automatic mode: The car defaults to tracking along a preset trajectory (the tracking circuit detects path deviations and corrects them). If it deviates from the trajectory, it will automatically adjust; when there is no preset trajectory, the car moves forward at a constant speed, and multiple sensors detect fire scene information in real time; [1]

• Fire source response: After AC4067 detects a flame, STM32 calculates the direction of the fire source, controls the L298N to drive the motor to turn towards the fire source, and the E18-D80NK obstacle avoidance sensor detects obstacles in real time and detours around them;

• Fire extinguishing and alarm: When the car reaches within 50cm of the fire source, and DS18B20 detects a temperature of ≥ 50°C or MQ-2 detects a smoke concentration of ≥ 1000 ppm, the STM32 triggers the buzzer to alarm, and at the same time controls the relay to start the desiccant spraying equipment for fire extinguishing.

3. System Hardware Design

3.1. Main Control Chip Circuit

The minimum system circuit of STM32F103C8T6 is shown in Figure 1, and its core includes:

• Power circuit: The VBAT pin is connected to a 3.3V lithium battery (backup power supply), and the VCC pin is connected to a 5V to 3.3V voltage regulator module to ensure stable power supply; VSS_1, VSS_2, and VSSA are grounded to reduce power noise;

• Clock circuit: OSCIN (pin 5) and OSCOUT (pin 6) are externally connected to an 8MHz crystal oscillator, which forms an external clock together with a 20pF capacitor to provide a stable clock signal for the microcontroller (which can be frequency-multiplied to 72MHz);

• Reset circuit: The NRST (pin 7) is connected to a 10KΩ pull-up resistor and a 0.1μF capacitor to achieve power-on automatic reset, ensuring stable system startup;

• Download interface: SWCLK (pin 37) and SWIO (pin 34) are SWD download interfaces, used for program burning and online debugging.

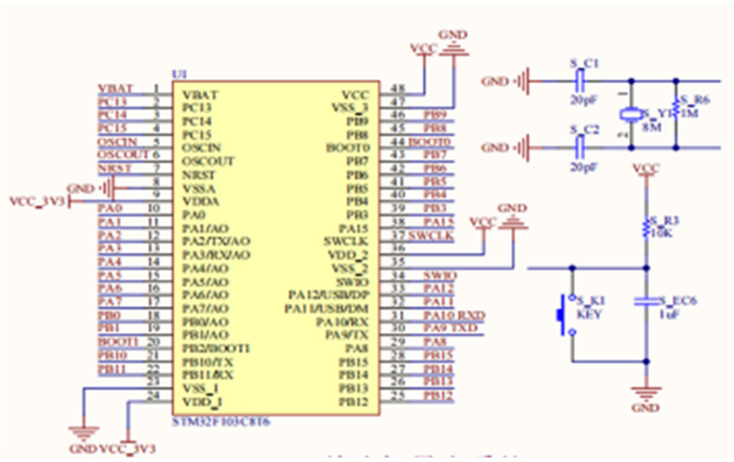

Figure 1. STM32 minimum system circuit

This circuit features low power consumption and strong anti-interference capability, and can be directly connected to the pins of various sensors and actuators (for example, PB11 is connected to DS18B20, and PB10 is connected to AC4067).

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3.2. Design of Temperature Detection Circuit

The DS18B20 temperature detection circuit is shown in Figure 2, using a three-wire connection: Pin 1 (GND) is connected to the ground; Pin 2 (DQ) is connected to the PB11 pin of STM32, and is also connected to 3.3V through a 4.7KΩ pull-up resistor. 3.3V, ensuring the bus is at high level when idle; pin 3 (VCC) is connected to a 3.3V power supply. [2]

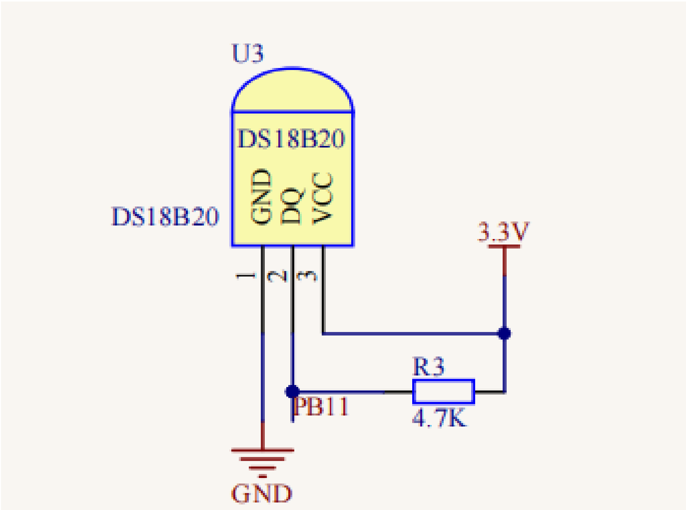

Figure 2. Temperature detection circuit

The DS18B20 contains a 64-bit ROM (unique address), a temperature sensor, and TH/TL registers (temperature alarm thresholds) internally. After temperature conversion, the STM32 sends commands via the 1-Wire bus (0xCC to skip ROM, 0x44 to start conversion, 0xBE to read data) to read 16-bit temperature data (the high 8 bits are the sign bit, and the low 8 bits are the decimal part). If the temperature is higher than TH (50°C by default) or lower than TL (-10°C by default), an alarm will be triggered.

3.3. Design of Flame Detection Circuit

The AC4067 flame detection circuit is shown in Figure 3. The VCC pin is connected to a 5V power supply, and the GND is grounded; the DO pin (digital output) is connected to the PB10 pin of STM32, and the AO pin (analog output) is left floating (this design uses digital quantities for simplified control); the circuit has a built-in comparator. When the detected flame infrared signal intensity exceeds the threshold, the DO outputs a low level; when there is no flame, it outputs a high level.

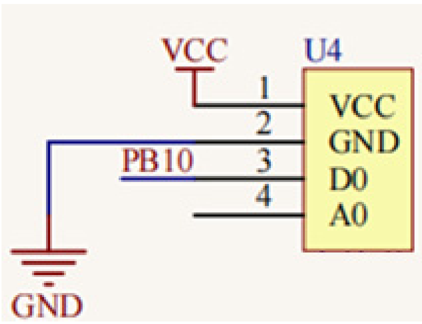

Figure 3. Flame detection circuit

STM32 determines the presence of a fire source by polling the level of the PB10 pin: if a low level is detected continuously for 500ms, it confirms the existence of a fire source, and then judges the direction of the fire source through the left and right sensors (expandable to dual sensors) (for example, if the left sensor is at a low level, it turns left).

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3.4. Smoke Detection Circuit Design

The MQ-2 smoke detection circuit is shown in Figure 4, and its core components include:

• Power supply: The 3 pins on the left are connected to a 5V power supply (the middle pin is the heating voltage to ensure the activity of the SnO_{2} material), and the middle pin on the right is grounded;

• Signal acquisition: The two pins on the right side are signal output terminals, connected to the PA0 pin (ADC input) of STM32, and a 4.7KΩ resistor is used for voltage division at the same time.

• Heating protection: The circuit has a built-in heating wire current-limiting resistor to prevent the heating wire from overheating and damaging the sensor.

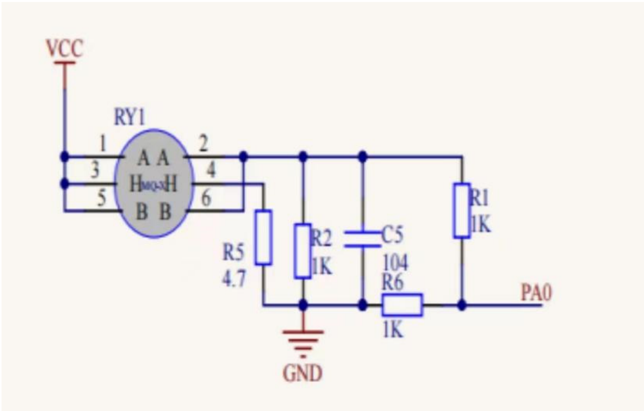

Figure 4. Smoke detection circuit

During operation, the MQ-2 needs to be preheated for 30 seconds (to ensure that SnO_2 reaches a stable working state). The higher the smoke concentration, the smaller the sensor resistance and the higher the output voltage; the STM32 collects the voltage of the PA0 pin (0~3.3V) through the ADC and converts it into smoke concentration (the voltage has a linear relationship with the concentration). If the concentration ≥1000 ppm, an alarm will be triggered. [3]

3.5. Obstacle Avoidance Circuit Design

The E18-D80NK obstacle avoidance circuit is shown in Figure 5. VCC is connected to a 5V power supply, and GND is connected to the ground; the OUT pin is connected to the PB5 pin of STM32, outputting a digital signal; the detection distance (0~80cm) can be set by adjusting the sensor potentiometer. [4]

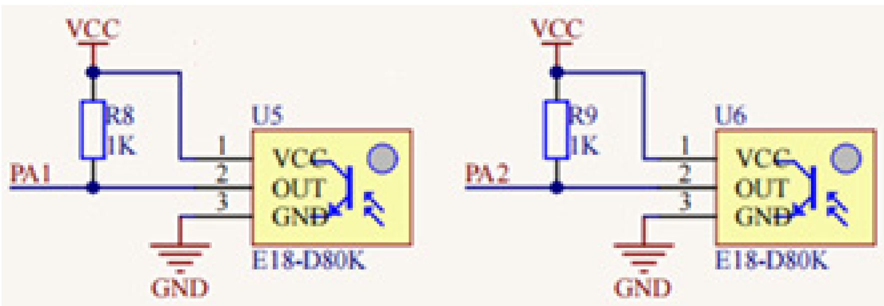

Figure 5. Obstacle avoidance circuit

When an obstacle is detected, the infrared rays emitted by the sensor are reflected, the internal NPN triode is turned on, the OUT outputs a low level, and the indicator light is on at the same time; when there is no obstacle, the OUT outputs a high level. The STM32 polls the PB5 pin: if a

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low level is detected, it controls the motor direction (such as turning right when avoiding obstacles on the left), realizing automatic obstacle avoidance.

3.6. Buzzer Alarm Circuit Design

The buzzer alarm circuit is shown in Figure 6. One end of the buzzer is connected to a 5V power supply, and the other end is connected to the collector of the NPN transistor Q1 (8050); the base of Q1 is connected to the PB1 pin of STM32 through a 1KΩ resistor, and the emitter is grounded.

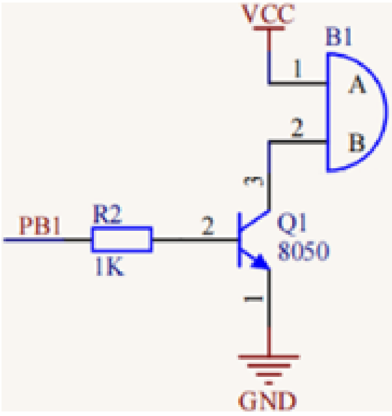

Figure 6. Buzzer alarm circuit

When the temperature/smoke exceeds the limit or a fire source is detected, the STM32 controls PB1 to output a high level, Q1 is turned on, and the buzzer is powered on to sound (with a frequency of approximately 2kHz); when PB1 outputs a low level, Q1 is turned off, and the buzzer stops, realizing the sound and light alarm function.

3.7. Design of Drive Motor System

The L298N drive motor circuit is shown in Figure 7, which controls two DC deceleration motors (the left motor is connected to OUT1/OUT2, and the right motor is connected to OUT3/OUT4). VCC2 is connected to 6V lithium battery (motor power supply), VCC is connected to 5V (chip logic power supply), GND is grounded; EN1 (left motor enable) is connected to PB3 of STM32, EN2 (right motor enable) is connected to PB8, and the high level is effective (PWM output can adjust the motor speed); IN1 (left motor forward) is connected to PB4, IN2 (left motor reverse) is connected to PB5; IN3 (right motor forward) is connected to PB6, IN4 (right motor reverse) is connected to PB7.

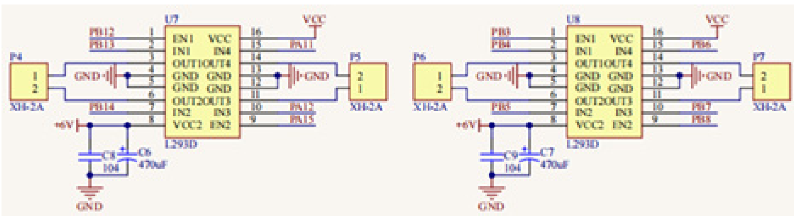

Figure 7. Drive motor circuit

The motor action is realized by controlling the IN1~ IN4 level: the left/right motor rotates forward at the same time (IN1 =H, IN2=L; IN3 =H, IN4 = L), the trolley advances; the left motor stops (EN1=L), the right motor rotates forward, the trolley turns left; the right motor stops, the left motor rotates forward, and the trolley turns right.

4. System Software Design

The main program adopts a modular design, and the flow is shown in Figure 8.

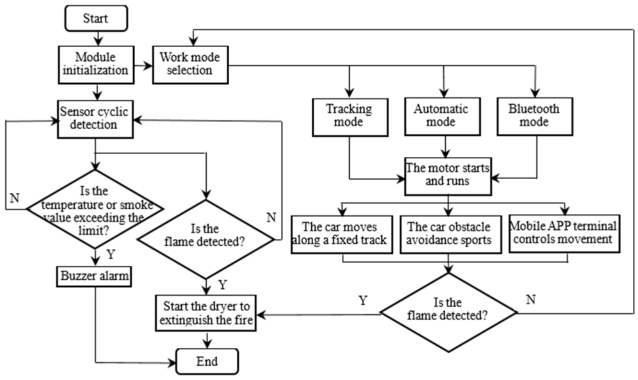

Figure 8. Main program flow chart

The core steps are:

• Initialization: After the system is powered on, initialize the STM32 clock (72MHz), GPIO ports (sensor/actuator pins), ADC (smoke detection), UART (Bluetooth), and timer (PWM motor speed regulation);

• Mode selection: The system enters automatic mode by default, and can be switched to tracking mode or manual mode via Bluetooth commands;

• Sensor detection: In automatic mode, poll data from AC4067 (flame), DS18B20 (temperature), MQ-2 (smoke), and E18-D80NK (obstacle avoidance);

• Logical judgment: If a flame is detected and the temperature/smoke exceeds the limit, the buzzer is triggered to alarm, and the motor is controlled to turn to the fire source while avoiding obstacles; if no flame is detected, the car moves forward at a constant speed or follows the track.

• Fire extinguishing execution: After the car reaches the vicinity of the fire source, the STM32 controls the relay to close and starts the desiccant spraying device (for 10 seconds continuously). After the fire is extinguished, it resets to the detection state.

5. Conclusion

This paper designs an intelligent fire-extinguishing trolley based on STM32F103C8T6, which realizes accurate fire source detection through multi-sensor fusion, and combines L298N motor drive and Bluetooth control to achieve automatic fire extinguishing. In terms of hardware, low-power consumption and high-stability components are selected to simplify the circuit design; in terms of software, modularization and interrupt mechanisms are adopted to improve the system response speed. Tests show that the trolley's flame detection distance reaches 80cm, obstacle avoidance accuracy is ±2cm,fire extinguishing response time ≤10s, and it can effectively handle initial fires. Future optimization directions: adding a Wi-Fi module to realize remote monitoring, upgrading image recognition technology to improve fire source positioning accuracy, adapting to higher-power fire-extinguishing actuators (such as small sprinkler devices), and further expanding application scenarios.

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