Simulation Design of an Intelligent Range Hood System Based on the STC89C52

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Abstract: Addressing the shortcomings of traditional range hoods, such as a lack of intelligence, the absence of environmental safety monitoring, and the inability to dynamically adjust fan speed, this paper presents the design of an intelligent range hood control system based on the STC89C52. The system collects kitchen environmental data using MQ-2, MQ-4, temperature, photoresistor sensors, and combines with the MX1508 motor driver, a buzzer, an LCD1602 display, and independent buttons. It enables fan speed control, alarm functions, and human-machine interaction. Verified through Proteus simulation, the system can reliably achieve environmental monitoring, intelligent speed control, and safety alarms, with intelligence and safety performance superior to those of traditional range hoods.

Keywords: STC89C52 microcontroller, intelligent range hood, multi-sensor, PWM speed control, Proteus simulation

1. Introduction

In recent years, with the rapid rise of the intelligent home industry and the public's pursuit of high-quality life, the demand for intelligent upgrades in the kitchen, the central hub of family life, has become increasingly prominent. Traditional range hoods have long been constrained by a mechanical operating mode characterised by manual switching and manual fan speed adjustment, and are now struggling to meet users' increasing demands for intelligent, convenient, energy-efficient, and safe kitchen appliances. Consequently, this paper utilises the STC89C52 microcontroller as its core control unit and, based on the Proteus simulation platform, has designed an intelligent range hood system. This system features multiple functions, including automatic smoke concentration monitoring, adaptive fan speed adjustment, temperature and brightness alerts, and real-time gas leak alarms. The design of this system not only enhances the performance and efficiency of the range hood, but also improves the user experience [1]. It is also consistent with current concepts of low-carbon and environmentally sustainable practices, offering significant potential for further development.

2. Overall Design

In terms of environmental sensing, the system uses temperature sensors, photoresistors, an MQ-2 smoke sensor, and an MQ-4 gas sensor to collect real-time data of the kitchen environment. Smoke and gas concentrations are measured every 500 ms, which effectively minimises the risk of safety hazards. Regarding fan speed control, the PWM duty cycle of the motor is dynamically adjusted based on smoke concentration levels, with five adjustable settings. This ensures effective smoke extraction while reducing energy consumption, enabling unattended, intelligent operation. Regarding safety alerts, a message is sent via the serial port when the temperature exceeds a set threshold, and another when the brightness falls below a set threshold. Smoke concentration is monitored by the MQ-2 sensor and an alert is triggered and a message is sent when the concentration exceeds the initial set value. Gas concentration is monitored by the MQ-4 sensor, combined with a buzzer module to provide an alarm [2]. The system design block diagram is shown in Figure 1.

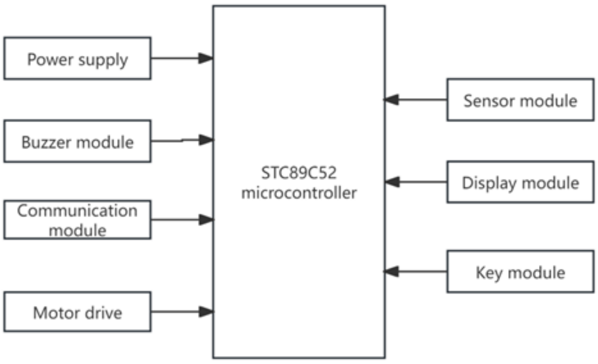

Figure 1: System Design Block Diagram.

3. Main Components

3.1 Master Controller

The STC89C52 microcontroller is an 8-bit microcontroller based on the 8051 core, with an operating voltage range of 3.3V to 5.5V and a maximum operating frequency of 48MHz. It features 8K bytes of program storage capacity and 512 bytes of RAM, supports ISP and IAP functions, and integrates up to 32 GPIO, three 16-bit timers or counters, four external interrupts, and a universal asynchronous serial port [3]. The microcontroller is responsible for receiving signals from the sensor module. It then evaluates these signals via its internal program logic and sends control commands to adjust the fan speed and trigger alarms.

3.2 MQ-2 Smoke Sensor

The MQ-2 smoke sensor is a sensor based on tin dioxide semiconductor, capable of detecting smoke concentration and providing both analog and digital output signals. Tin dioxide semiconductor is a surface-ionized N-type semiconductor material. At a working temperature ranging from 200 to 300℃, oxygen in the air adsorbs onto the surface of the tin dioxide, forming a layer of oxygen anions [4]. This layer of anions captures free electrons within the semiconductor, thereby reducing the electron density and increasing the resistance. When smoke comes into contact with the sensor, the gas reacts with the oxygen adsorption layer to release free electrons, thereby altering the surface conductivity. The smoke concentration can be inferred from the change in resistance.

3.3 MQ-4 Gas Sensor

The core component of the MQ-4 gas sensor is a tin dioxide sensing layer. When powered and heated, contact between the surface and combustible gases, such as methane or natural gas, triggers a chemical reaction, causing the resistance of the tin dioxide semiconductor to decrease. The extent of this decrease increases as the gas concentration rises. Once the gas concentration is detected, the output signal undergoes analog-to-digital conversion to yield a numerical value. The MQ-4 sensor exhibits high sensitivity to combustible gases and also demonstrates good sensitivity to propane and butane [5].

3.4 Temperature Sensor

Based on the temperature characteristics of a semiconductor PN junction, the continuous analog voltage output from the sensor is converted by an ADC into a discrete digital signal that can be read by the microcontroller, thereby enabling temperature detection.

3.5 Photoresistor

The photoresistor converts light signals into electrical signals based on the photoelectric effect. When light strikes the sensor surface, the energy of the photons is absorbed by electrons, triggering a change in their state and thereby generating a current or voltage signal [6]. After analog-to-digital conversion, this signal is sent to the microcontroller to enable brightness detection.

3.6 Buzzer

A buzzer is an integrated electronic sounder that can be driven by direct current. Active DC-driven buzzers incorporate an internal oscillation circuit; when a DC voltage is applied, current flows through the internal oscillation, amplification and sampling circuits to produce sound via a resonant device.

3.7 LCD1602

As a general character liquid crystal display, the LCD1602 integrates multiple types of components，mainly including the character LCD panel, the HD44780 driver controller, and the HD44100 expansion driver, together with peripheral components such as resistors and capacitors. The entire welding is carried out within the PCB substrate. The LCD1602 can display numbers, English characters, simple graphics, and custom special characters. It features a two-line layout, each line capable of displaying 16 characters. There are 16 hardware pins in total, comprising an 8-bit data transmission channel D0 to D7 and three types of control signal interfaces: RS, R/W, and EN. The device is rated for a 5V operating voltage and is equipped with a V0 contrast adjustment pin and backlight power supply pins A and K, which are used to adjust screen clarity and control backlight illumination, respectively.

4. Circuit Design

4.1 Circuit Diagram

The complete circuit diagram of the intelligent range hood system is shown in Figure 2.

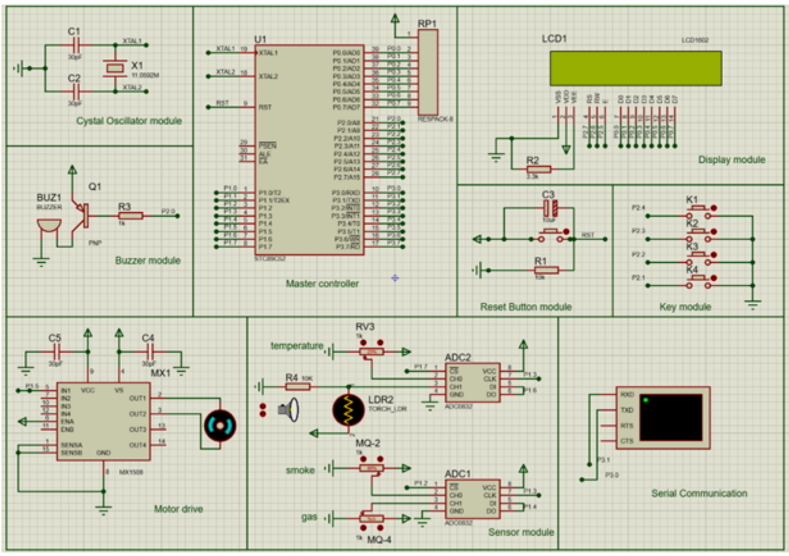

Figure 2: Circuit Diagram.

4.2 Master Controller Circuit

As the core of the system, the microcontroller receives input signals from various modules, such as button commands and ADC conversion data. After processing these via internal program logic, it outputs control signals to drive the motor, trigger the buzzer, and refresh the screen display, while coordinating modules such as the crystal oscillator and reset circuit to ensure stable system operation [7].

As shown in Figure 3, VCC is connected to a +5V power supply and GND is grounded, providing the microcontroller with operating voltage. pin P1.5 is connected to the IN1 pin of the MX1508 motor driver chip, outputting a PWM signal to control the fan speed; pin P2.0 is connected to a PNP transistor driving the buzzer module, controlling the activation and deactivation of the alarm; pins P1.2, P1.7, P1.3, P1.4, and P1.6 are connected to the CS, CLK, DO, and DI pins of the ADC0832, respectively, to receive digital signals converted from analog inputs; pins P3.0 and P3.1 correspond to the TXD and RXD pins of the serial communication module, enabling data transmission and reception between devices. Pins P0.0 to P0.7 are connected via a pull-up resistor network to the D0 to D7 data pins of the LCD1602; the LCD1602's RS, RW, and E control pins are connected to the microcontroller's pins P2.7, P2.6, and P2.5 respectively to configure the display data and screen commands. Pins P2.1 to P2.4 are connected to four independent push-button switches, which are used to receive manual user commands.

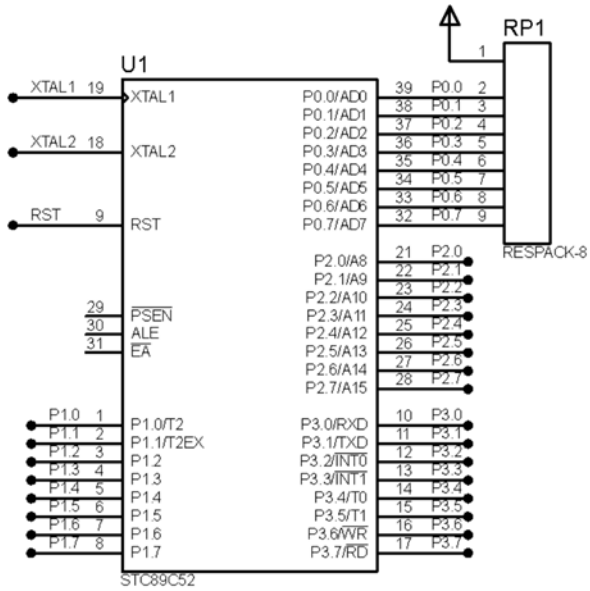

Figure 3: Master Controller Circuit.

4.3 Buzzer Circuit

When a gas leak is detected, pin P2.0 outputs a low level, driving the PNP transistor Q1 into conduction. The buzzer is powered and sounds an alarm to indicate danger. The emitter of the PNP transistor Q1 is connected to the 5V power supply; its collector is connected to the positive terminal of the buzzer BUZ1 while the negative terminal of the buzzer is directly grounded; a 1kΩ current-limiting resistor R3 is connected in series with the base, which is then connected to pin P2.0 of the microcontroller. When pin P2.0 outputs a high level, the potentials at the emitter and base are approximately equal, and the transistor is in the cut-off state; no current flows through the buzzer and it does not sound. When P2.0 outputs a low level, a forward bias voltage is applied between the emitter and base, causing the transistor to conduct; current flows through the buzzer, completing the circuit, and the buzzer operates. The buzzer circuit is shown in Figure 4.

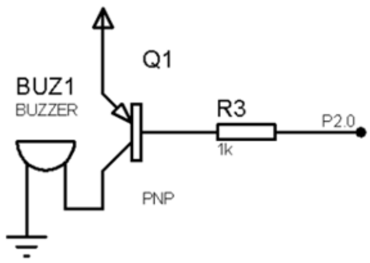

Figure 4: Buzzer Circuit.

4.4 Serial Communication Circuit

The system uses the UART communication protocol to enable data exchange with the host computer, allowing the upload of monitoring data such as temperature, brightness, concentration, and wind speed. As shown in Figure 5, the module's TXD pin is connected to the microcontroller's P3.0 pin, and its RXD pin to P3.1, enabling bidirectional data transmission.

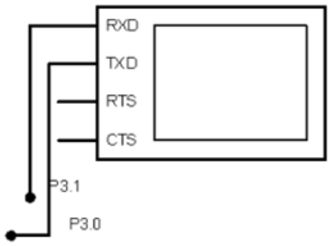

Figure 5: Serial Communication Circuit.

4.5 LCD1602 Display Circuit

The 16-column by 2-row display outputs real-time system status data, including mode, fan speed, temperature, brightness, smoke concentration, and gas concentration [8]. As shown in Figure 6, D0-D7 are connected to the microcontroller's P0.0-P0.7 pins, respectively; RS is connected to the microcontroller's P2.7 pin, transmitting display data when high and control commands when low; RW is connected to the microcontroller's P2.6 pin, switching between LCD read and write modes; and E is connected to the microcontroller's P2.5 pin. Control commands are received and executed when the E pin transitions from high to low. VSS is connected to ground, VDD to +5V, and VEE is the LCD contrast pin, which is connected to ground via a 3.3 kΩ resistor R2 in series; contrast is at its lowest when connected to VDD and at its highest when connected to ground.

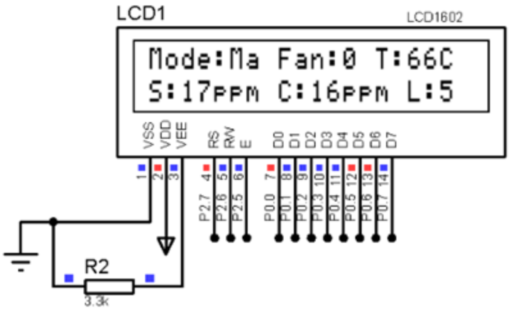

Figure 6: LCD1602 Display Circuit.

4.6 Sensor Circuit

The sensor circuit converts the 0–5 V analog signals from the temperature, brightness, smoke sensor, and MQ-4 gas sensor into 8-bit digital signals, which are then transmitted to the microcontroller for data processing, thereby enabling the monitoring of environmental parameters.

As shown in Figure 7, the system uses two ADC0832 analog-to-digital converter chips for environmental analog signal acquisition; both chips share the microcontroller's P1.3 pin as the clock signal line[9]. The chip select pin of ADC2 is connected to P1.7 and the data pin to P1.6; the CH0 channel receives the analog temperature signal from the 1 kΩ potentiometer RV3, while the CH1 channel receives the light intensity signal from the voltage divider circuit of the light-dependent resistor LDR2; the chip select pin of ADC1 is connected to P1.2 and the data pin to P1.4; the CH0 channel receives the voltage divider signal from the MQ-2 smoke sensor, while the CH1 channel receives the voltage divider signal from the MQ-4 gas sensor. The continuous analog voltages from the various sensors are converted into digital signals by the ADC0832 and then transmitted to the microcontroller for processing.

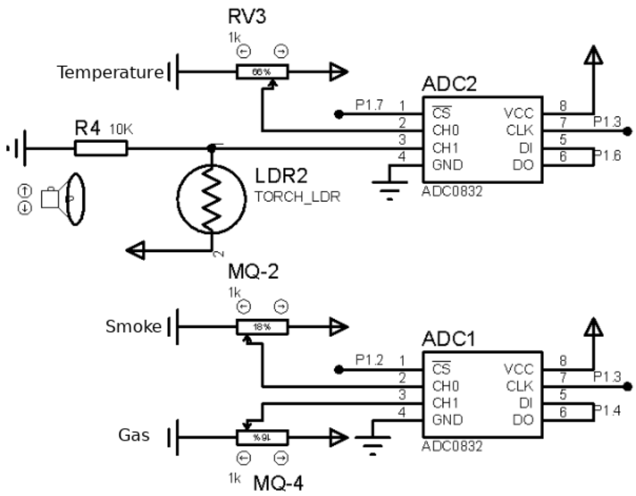

Figure 7: Sensor Circuit.

4.7 Button Circuit

As shown in Figure 8, the system comprises four independent buttons. The buttons act as a human-machine interface. When a user presses a button, a level signal is sent to the microcontroller, triggering the corresponding function. Pressing K2 allows the user to switch freely between automatic and manual modes. In manual mode, pressing K3 increases the fan speed while pressing K4 decreases it. In automatic mode, the fan speed is adjusted according to the smoke concentration; the higher the smoke concentration, the faster the motor runs. Gas concentration is monitored separately for alarm triggering. Pressing K1 allows the user to set the thresholds for temperature, brightness, smoke concentration, and gas concentration; at this point, K2 acts as the increase button and K3 as the decrease button. Pressing K1 again cycles through the parameter settings. One end of K1–K4 is grounded, while the other ends are connected to the microcontroller's P2.1–P2.4 pins, respectively.

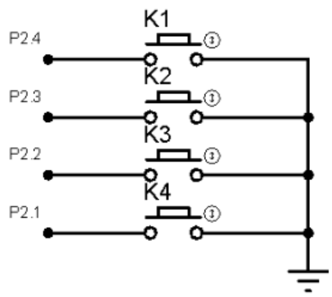

Figure 8: Button Circuit.

4.8 Motor and Driver Circuit

The MX1508 DC motor driver IC's VCC and VS pins are connected to a 5V power supply, with 30pF capacitors C5 and C4 respectively providing power supply filtering; the common GND pin is connected to system ground. The control pin IN1 is connected to the microcontroller's P1.5 pin to output a PWM signal. A PWM signal is a square wave; by altering the duty cycle of its high level—that is, the proportion of the high-level duration relative to the entire cycle—the average voltage across the motor terminals can be controlled, thereby regulating the rotational speed. The higher the duty cycle, the faster the motor rotates; the lower the duty cycle, the slower the motor rotates. Set ENA to a high level to enable the circuit; short the current detection pins SENSA and SENSB to ground to disable the current monitoring function; connect DC fans to the OUT1 and OUT2 ports. As shown in Figure 9.

When using PWM to control the motor, the duty cycle is defined as:

$$D=\frac{t_{on}}{T}=\frac{t_{on}}{t_{on}+t_{off}} \tag{1}$$

where T is the total PWM period, is the duration of the high-level signal, and t_{off} is the duration of the low-level signal.

The average power of the motor is defined as:

$$P=DP_{max} \tag{2}$$

where D is the duty cycle, P_{max} is the full power of the motor during operation, and is the motor power. From Equation (2), it can be seen that the duty cycle determines the average input power of the motor; the greater the power, the higher the rotational speed.

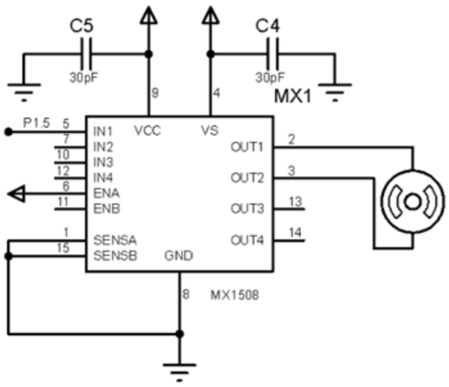

Figure 9: Motor and Drive Circuit.

4.9 Crystal Oscillator Circuit

The crystal oscillator circuit provides a stable system clock reference for the STC89C52 microcontroller and forms the timing basis for the normal operation of the microcontroller program. As shown in Figure 10, this circuit consists of an 11.0592 MHz passive crystal oscillator X1 and two 30 pF ceramic capacitors, C1 and C2. The crystal oscillator X1 is connected to the microcontroller's XTAL1 and XTAL2 clock pins, respectively; one end of capacitor C1 is connected to XTAL1 and the other to ground, while one end of capacitor C2 is connected to XTAL2 and the other to ground. These two capacitors act as start-up load capacitors, matching the internal equivalent resonant circuit of the crystal oscillator to assist in initiating and stabilising the oscillation frequency; the 11.0592 MHz standard crystal oscillator meets the frequency division requirements for serial communication, preventing baud rate errors during the transmission and reception of serial data, and providing a unified timing reference for the microcontroller system.

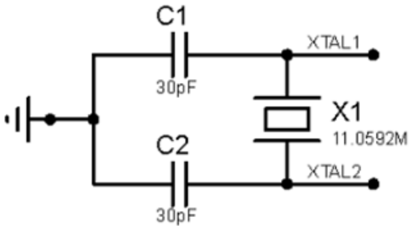

Figure 10: Crystal Oscillator Circuit.

4.10 Reset Circuit

The reset circuit integrates both automatic power-on reset and manual button reset functions. As shown in Figure 11, the circuit comprises a 10 μF capacitor C3, a 10 kΩ resistor R1, and a reset button. The capacitor C3 is connected between the 5V power supply and the RST pin, while resistor R1 normally pulls the RST pin low to ground. Upon power-up, the capacitor charges to generate a high-level reset signal; pressing the button also pulls the RST pin high to initiate a manual restart. These two reset methods ensure that the microcontroller can quickly return to its initial operating state in the event of a program malfunction.

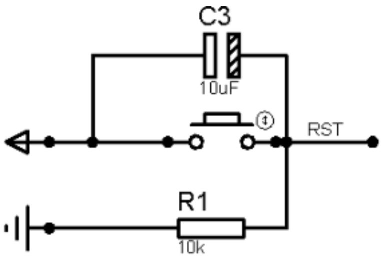

Figure 11: Reset circuit.

5. System Software Design

5.1 Introduction to Programming Software

The system software is developed using Keil uVision5, an integrated development environment for embedded microcontrollers. It is a software suite comprising a source code editor, a debugger, and other tools required for microcontroller development, debugging, and programming. In this work, Keil is used to write and compile the C51 program for the STC89C52, generating a .hex object file for subsequent simulation. It offers a user-friendly graphical interface, supports multiple programming languages including C and C++, and provides powerful code editing and debugging features such as syntax highlighting, an integrated debugger, and code coverage analysis.

5.2 Introduction to Proteus Software

Proteus is an EDA tool developed by Lab Center Electronics in the UK. It integrates schematic capture, SPICE mixed-signal simulation, and microcontroller hardware-software co-simulation capabilities, with a rich library of component models and virtual test instruments, and supports co-simulation for various mainstream microcontrollers.

5.3 Main program Design

As shown in Figure 12, the program first completes initialization and pin configuration, then sequentially acquires four types of environmental parameters—temperature, brightness, smoke, and gas—and updates the LCD in real time to display the monitored values. The program continuously monitors button states; if a button is pressed, the user can set thresholds for environmental parameters and switch the motor's operating mode. In automatic mode, the system automatically adjusts the motor speed based on gas concentration. The program then checks whether the smoke concentration exceeds the set threshold; if it does, the buzzer sounds an alarm, and if it remains within limits, the serial port outputs a reminder message regarding the environmental parameters. After completing one cycle, the program resumes collecting environmental data.

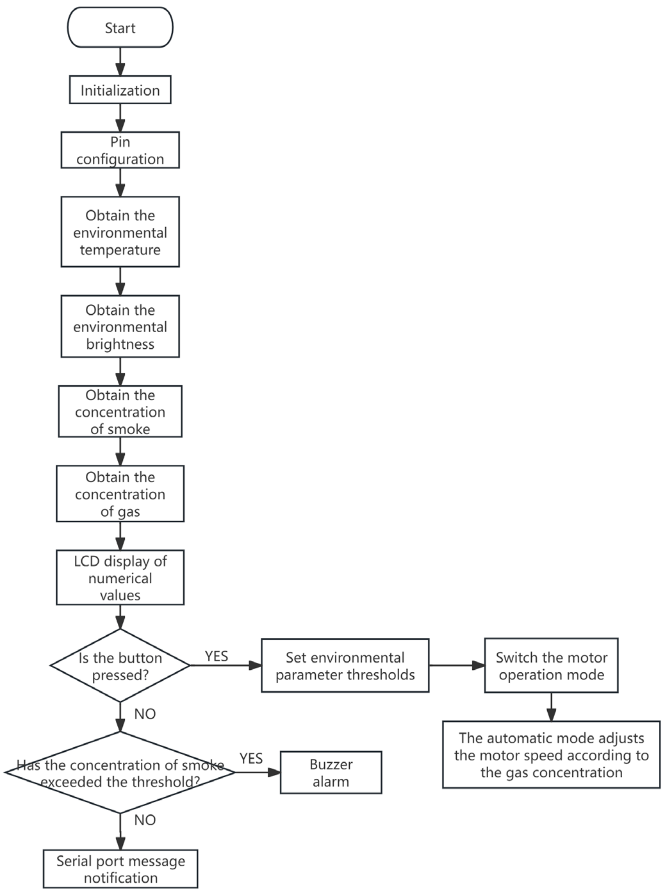

Figure 12: Main program Flowchart.

5.4 Key Code

```
I. Sensor detection function
void Monitor_function(void)
 {
  if(time_num % 50 == 0)                                                    // Check every 500 ms
  {
        smog_value = Adc08321_Get_Value(0)/256.0* 100; //Retrieve smoke concentration
        CH4_value = Adc08321_Get_Value(1)/256.0* 100;      //Retrieve gas concentration
        temperature_value = Adc08322_Get_Value(0)/256.0*100;   // Retrieve temperature
        luminance_value = Adc08322_Get_Value(1)/256.0*100;     // Retrieve brightness
  }
 }
```

```
II. Motor speed control function
 void Manage_function(void)
 {
 if(flag_display == 0)
  {
        switch(speed_value)          // Gear position is linked to engine speed
        {
              case 0:     // Gear 0, maximum speed, minimum duty cycle, fan at lowest speed
                    speed = 10;
              break;
              case 1:
                    speed = 8;
              break;
              case 2:
                    speed = 6;
              break;
              case 3:
                    speed = 4;
              break;
              case 4:
                    speed = 3;
              break;
              case 5:              // Gear 5: minimum speed, maximum duty cycle, maximum fan
speed
                    speed = 0;
              break;
 }}
```

```
//In automatic mode, the range hood's speed is proportional to the smoke concentration
  if(mode == 0)
{
        if(smog_value < 90)
            speed_value = smog_value / 20;
        else        //When the smoke concentration exceeds 90, the speed is adjusted to the
maximum
            speed_value = 5;
  }
 Buzzer alarm function
  if(CH4_value > CH4_max)
  {
        if(time_num % 30 == 0)
            BEEP = ~BEEP;
        if(send_flag_CH4 == 0)
       {
            send_flag_CH4 = 1;
            Uart1Sends("Gas concentration too high\r\n");
         }}
  else
  {
        BEEP = 1;
        send_flag_CH4 = 0;
}
```

6. Testing and Analysis

After entering the Proteus main interface and drawing the system hardware schematic, double-click the microcontroller to load the .hex file successfully.

After running the simulation, the system automatically detects the current ambient temperature, brightness, smoke concentration, and gas concentration, and displays these on the LCD screen. Figure 13 shows the content displayed on the LCD1602 screen.

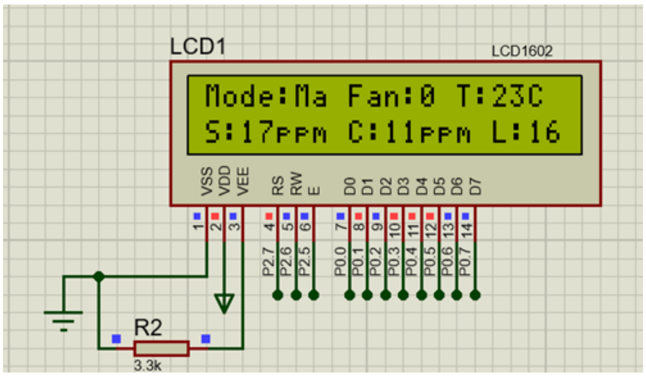

Figure 13: Display content.

Use the buttons to set the thresholds for temperature, brightness, smoke concentration, and gas concentration, and to switch the motor between automatic and manual modes. In automatic mode, the motor starts when smoke or gas concentration levels exceed the threshold value; furthermore, the higher the gas concentration, the faster the motor speed. In manual mode, a total of five speed settings can be selected via the buttons. Figure 14 shows the initial thresholds, while Figure 15 illustrates the switching of the motor's operating mode.

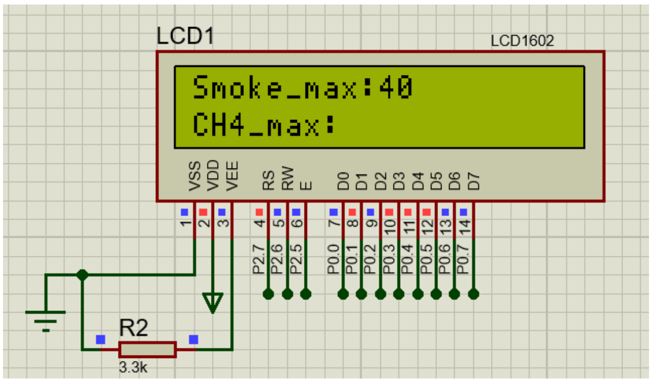

Figure 14: Setting initial threshold values for parameters.

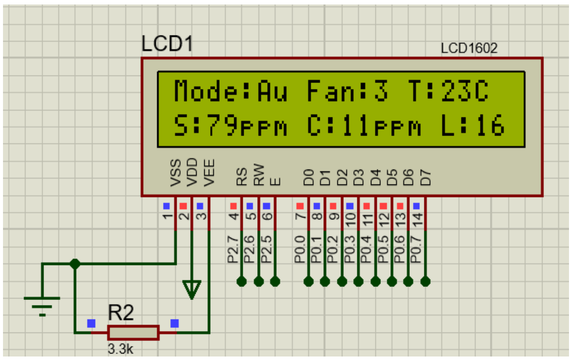

Figure 15: Motor Mode Switching.

When the ambient temperature is too high, the ambient light level is too low, or the smoke and gas concentrations are too high, a notification message will be sent to the terminal.

Alarm function: When the gas concentration reading exceeds the threshold, the buzzer sounds to alert the user.

7. Conclusion

This paper describes the design of an intelligent range hood control system based on the STC89C52 microcontroller. The system uses various sensors to collect kitchen environmental parameters and employs the MX1508 to output PWM signals for five-speed fan control. Combined with an LCD1602 display, buttons, a buzzer, and a serial port module, the system enables human-machine interaction, manual/automatic mode switching, buzzer alarms, and host computer alerts. The system's hardware circuitry was modeled in Proteus, while the software was developed using Keil for modular programming. Simulation results indicate that all functions operate stably and offer greater intelligence and safety compared to traditional range hoods.

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