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Indoor Air Quality Monitoring and Automatic Ventilation System

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A B S T R A C T

Arduino is a versatile and cheap device that can be used to perform various tasks. Arduino with its IDE is widely used to reliably automate different tasks. In this project an Arduino will be used in conjunction with a gas sensing module to monitor air quality in an enclosed space and take actions to prevent accumulation of gases if necessary. The gas sensor will be used to detect the concentration of any combustible or harmful gases and an Arduino will be programmed to automatically check the concentration. If higher than safe concentration of toxic and combustible gases is detected, a system will audibly and visually warn the inhabitants while actively preventing the accumulation of gas by venting the space through ventilation ducts and closing any supply valve if present.

Keywords: Arduino, Arduino IDE, Gas Sensor, Toxic Gas, Combustible Substance

1. Introduction

There are many hazards when it comes to enclosed spaces. Houses, ships and large facilities have various enclosed spaces where visits are not very frequent. Places like this can accumulate harmful gases or the concentration of CO2 or other toxic gas can get very high to the point that it is fatal to humans or other life forms. These enclosed spaces pose significant threats to any person entering the place. Also, if any space contains gas lines, especially in kitchens or industrial places, it can accumulate combustible gas and once it reaches a large enough concentration it can cause big explosions. The threat of LPG explosion is especially high as more and more restaurants and industries are being built which use LPG in various production also common household uses gas stoves for cooking which are prone to leakage. These poses danger to inhabitants and workers. All of which needs to be avoided as human life is at risk. To avoid these risks warning systems and prevention systems should be in place. This can be achieved by using sensors to sense the presence of harmful or combustible gases and available embedded systems like Arduino can be used to implement the system and sound warning signals. It can also be programmed to automatically ventilate the spaces so that the gases don't reach harmful constrictions. This will ensure the safety of inhabitants or workers in an industry.

1.1 Objectives

The objective of this project was to:

Design a system using Arduino to detect toxic and combustible gas.

Design a system to warn if gas is detected and prevent further accumulation of gas.

1.2 Project Outline

The gas detecting system will use an MQ2 sensor, LEDs and buzzer will be used to indicate safe and danger levels and the ventilation system will include a servo to open duct and a ventilation fan. An Arduino UNO microcontroller will be used to implement the system and Arduino IDE to program the microcontroller.

2. Literature Review

Gas related accidents are quite common, especially in indoor or enclosed spaces. Most of the time accidents are caused by accumulation of harmful or combustible gases. This accident can result in the harm or loss of human lives. So, systems that detect these gases and warn the inhabitants while preventing such accumulation is essential. In this study, an Arduino-based warning and ventilation system was developed for indoor spaces when harmful substances are detected. Several studies have been conducted on detection of these gases and developing a warning system.

In a study conducted by K. R. Katole , B. Bangade, V. Bagade and A. Soni, H. Kamde, a system was proposed which uses various sensors to detect several toxic or combustible gases like Butane, CO, C2 and show the accurate concentration on an LCD display.

In another study conducted by H. H. Yan and Y. Rahayu, a system was designed which ditects harmful gases and uses ZigBee to send the data reading from the gas sensor to monitoring system to display on LabVIEW GUI.

Another study conducted by M. A. Baballe and M. I. Bello proposed an Arduino based gas alarm detection system that will prevent gas explosion-related accidents.

Moreover, A. Y. Nasir, U. I. Bature, N. M. Tahir, A. Y. Babawuro, A. Boniface and A. M. Hassan proposed an Arduino based gas leakage control and temperature monitoring system which detects gas using gas sensor and warn the user if high gas concentration and temperature is detected.

A study was also conducted by N. M. Hussien, Y. M. Mohialden and N. T. Ahmed, M. A. Mohammed and T. Sutikno. In it an Arduino based system was proposed that detects gas leakage and uses GSM network to warn the user.

Overall, these studies show the effectiveness and potential of such Arduino based systems.

3. Methodology

The function of the intended system can be divided into four main processes. First to detect the gas using sensor and send signal to microcontroller, microcontroller process the signal and decides what routine to execute, warning system and ventilation system activated by the controller and finally the power supply to power the entire system.

3.1 Block Diagram

The diagram in Fig. 1 includes the components used and their primary connections. The system uses a gas sensor for sensing any toxic or combustible gases and ATMEGA 328P in an ARDUINO UNO is used as microcontroller. A 5 V voltage regulator is used to get a suitable fixed 5 V from a battery. Arduino and sensors are powered through this controlled stable supply. Various peripherals are controlled by the microcontroller to warn, ventilate, or cut off gas supply.

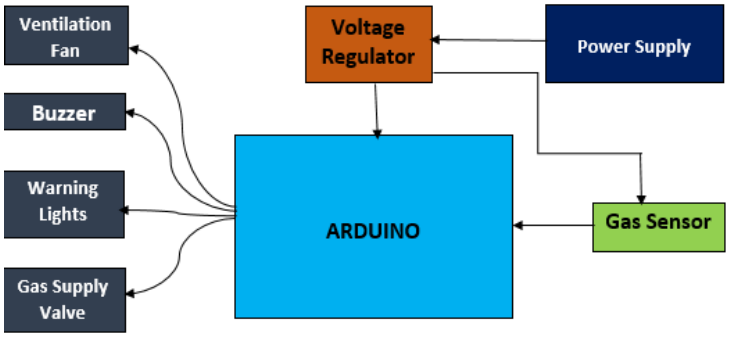

Fig. 1 - Block diagram of an Arduino based air quality monitoring and ventilation system.

3.2 Working Principle

The code with the system detects gas and executes proper routines accordingly. If no toxic or combustible gases are detected a green LED will show safe condition. As high concentration of gases is detected through the sensor and after concentration reaches a set threshold value program will execute gas detect routine and LED will start to blink RED, a buzzer will start to sound as warning. Also, the ventilation system will activate, a duct fan will turn on and any windows or locked cover will be opened to vent the space if possible and gas and if any gas supply valve exists it will be closed. If the gas concentration reaches normal level the system will execute gas norm routine and fans and covers will turn off and buzzer will stop also led will turn green. Along with the main detection system the system can be configured to automatically vent the space after a specified time.

3.3 Components

The components used in the system are widely available, easy, and cheap to implement.

a) Arduino UNO

Arduino Uno, as shown in Fig. 2 is a prototyping platform that is based on ATmega 328p microcontroller. It is an easy-to-use platform that is used to test and automate various tasks. It can be programmed with C, C++ or in Assembly language using the open-source Arduino IDE. Arduino can be paired with various sensors or modules to perform various tasks based on needs.

Fig. 2 - Arduino UNO.

b) MQ2 Gas Sensor

Gas sensors come in various models based on their sensitivity to different gases. MQ2 sensor can detect several types of gases like NO_3, CO_2, CO, LPG, and propane etc. It is most sensitive to combustible gases like LPG, propane and sensitive to CO_2 and CO. It can be used to detect the concentration of these gases in an enclosed space. An MQ2 gas sensor is shown in Fig. 3 below.

Fig. 3 - MQ2 gas sensor.

c) Warning and Ventilation System

The warning system consists of a buzzer and LED as shown in Fig. 4. When gas is detected, the buzzer sounds a tone and led flashes RED. The ventilation system includes a duct fan to ventilate the space and a motor to open windows or any covers.

Fig. 4 - Buzzer and ventilation fan.

d) Power Supply

The power supply shown in Fig. 5 consists of an LM7805 5V voltage regulator and a 9V battery. The voltage regulator regulates the voltage to around 5V as most of the sensors and components require a 5V to operate. Additionally, the Arduino can be powered using a 9V supply or from a connected computer through USB.

Fig. 5 - Battery and 5V Voltage Regulator.

3.4 Operation Flowchart

a) Main Loop

Fig. 6 depicts the operational flowchart of the main loop of our system.

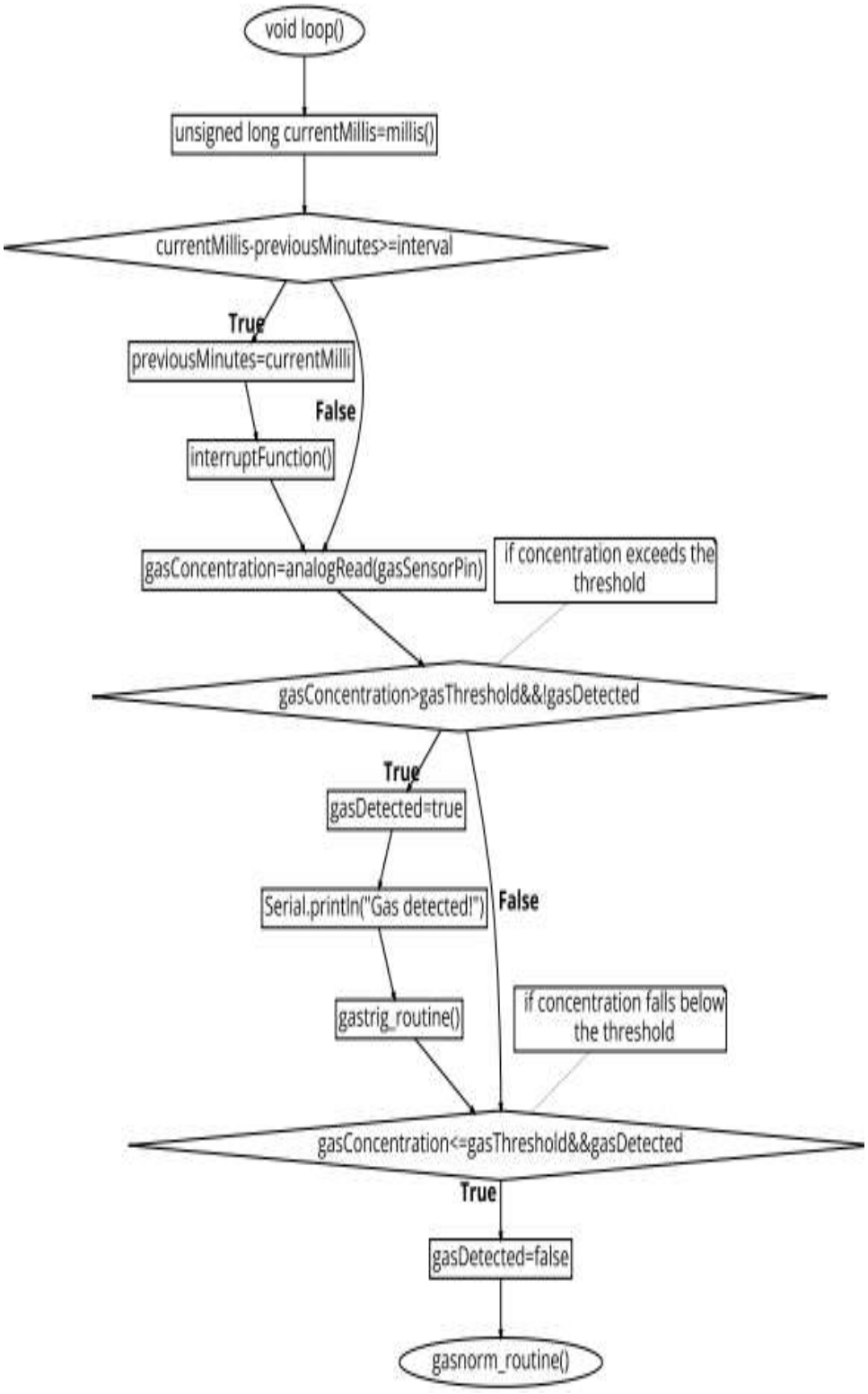

Fig. 6 – Main loop of the automatic ventilation system.

b) Routine Ventilation Operation Loop

Fig. 7 shows the routine ventilation operation loop of our system.

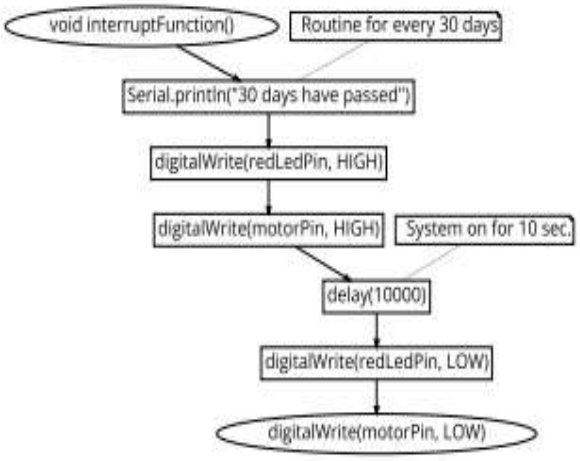

Fig. 7 – Routine ventilation operation loop of the automatic ventilation system.

c) Gas Trigger Routine Loop

Fig. 8 shows the gas trigger routine loop of our system.

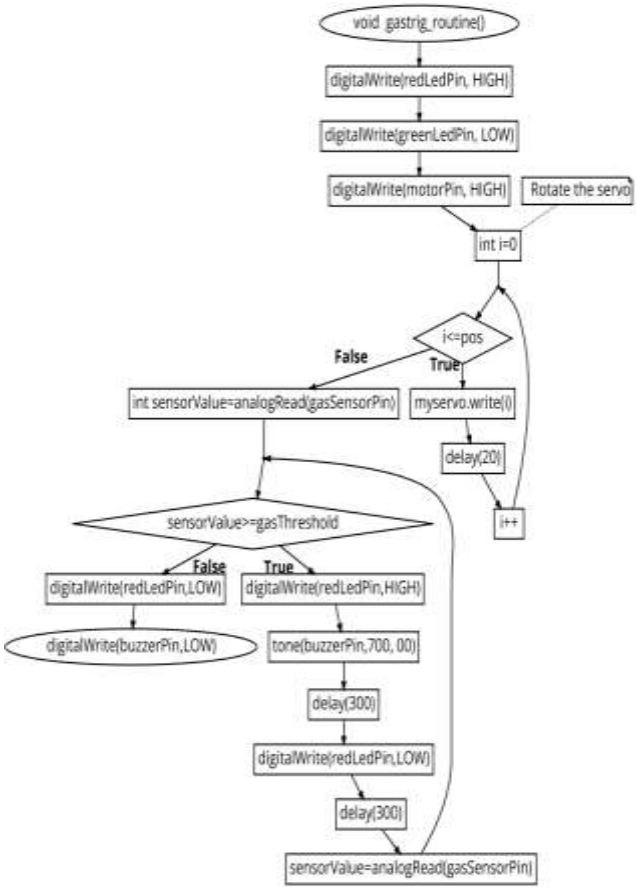

Fig. 8 – Gas trigger routine loop of the automatic ventilation system.

d) Normal Gas Condition Operation Loop

Fig. 9 depicts the flowchart of the system when gas conditions are in normal state.

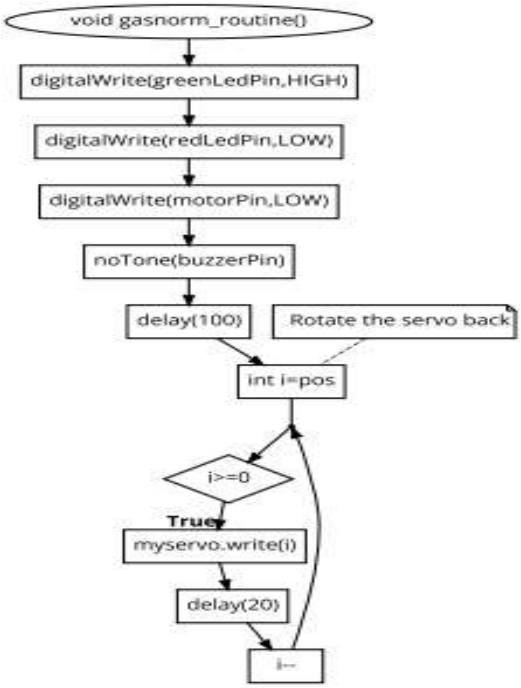

Fig. 9 – Normal gas condition operation loop of the automatic ventilation system.

4. Results and Discussion

The system was designed to be installed in enclosed spaces around household or industrial facilities where sensors will be situated in different enclosed spaces or potentially dangerous places. The system was tested in a model of an enclosed space and sensor was excited using butane gas. The experimental setup of our automatic ventilation system during normal operation is shown in Fig. 10. In normal operation, gas concentration is continuously measured and if the concentration is less than the threshold value (in this case 130), green LED is lit indicating safe conditions. During normal operation the monitored space is vented after a certain period to clean out stagnant air and prevent mold growth in enclosed places.

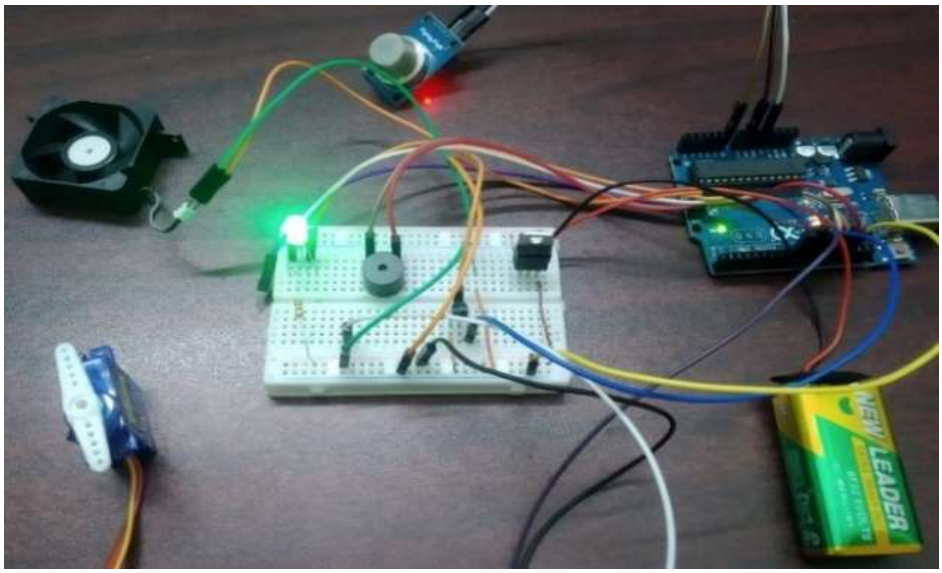

Fig. 10 – Experimental setup of the automatic ventilation system during normal operation.

The serial monitor of the Arduino IDE (Integrated Development Environment) shows the results obtained during normal operations as shown in Fig. 11.

```
Gas Concentration: 117
Gas Concentration: 117
Gas Concentration: 117
Gas Concentration: 117
*********30 days have passed!**********
Coducting Routine ventilation operation!
Back to normal operation!
Gas Concentration: 116
Gas Concentration: 116
Gas Concentration: 115
Gas Concentration: 115
Gas Concentration: 116
```

Fig. 11 – Arduino IDE serial monitor results during normal operation.

If gas concentration exceeds the threshold (test threshold = 130), gas_trig routine will be executed. If any gas supply valve is present it will be closed. The ventilation fan will turn on to prevent further accumulation and a buzzer will sound with blinking red light as warning as shown in Fig. 12. From serial monitor shown in Fig. 13, the function can be seen triggering after gas concentration gets high. The threshold value for the sensor is fixed after warm-up period and getting the nominal value for the enclosed space.

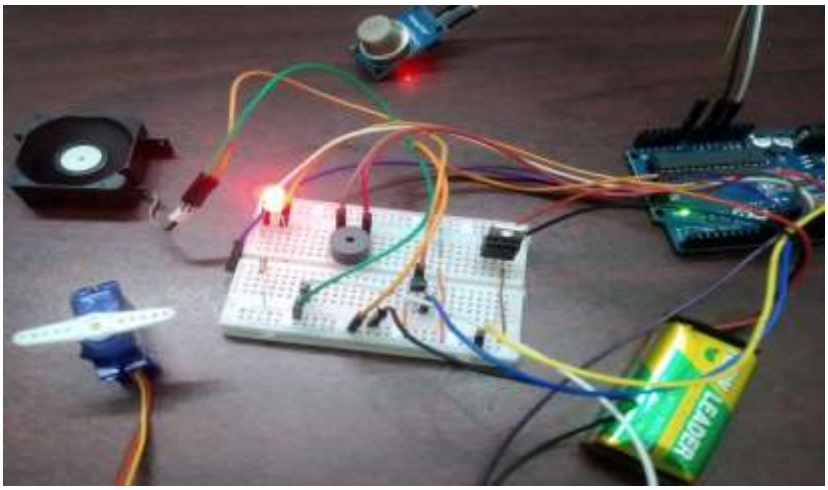

Fig. 12 – Experimental setup of the automatic ventilation system when gas is detected.

```
Gas Concentration: 130
Gas Concentration: 130
Gas Concentration: 131
**************Gas detected!*****************
Gas trigger routine started
Buzzer, ventilator fan online!
Valve closed!
Gas Concentration: 128
********Gas concentration back to normal!***
Gas Concentration: 128
Gas Concentration: 128
Gas Concentration: 128
Gas Concentration: 128
Gas Concentration: 128
Gas Concentration: 128
Gas Concentration: 128
```

Fig. 13 – Arduino IDE serial monitor results when gas concentration is high.

5. Future Potential

Even though the system worked according to our purpose, it can be improved to add more safety features. The system can be immigrated in the fire suppression system or security systems for more effective operation. Also, by using multiple gas sensors sensitive to different types of gas the system can be made more relatable and sensitive at detecting other harmful gas accumulations and overcome the sensitivity issue of single sensor-based system. Different sensors like infrared and heat sensors can be integrated in the system to detect small starting fires. Moreover, water sprinkler systems with valves can be installed to suppress any small fires upon detection. This will add another layer of security to the system.

6. Conclusion

Ensuring the safety of human life is usually the priority. Specially, preventing gas related accidents are crucial when it comes to safety as gas explosions are quite common now days. Also, there are many fatalities caused by suffocation or presence of toxic gases. These accidents usually occur in places like house-hold kitchens, industrial facility, or enclosed spaces without proper ventilations. In this project an Arduino based system was developed to detect the presence of any harmful gases and vent them. This system acts as a warning and prevention system. It can be installed in any setting and can warn people of possible hazards. Also, the system actively prevents such accumulation of gases. The system is cheap, can be easily implemented and can possibly save lives.

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Code for the Arduino

```
void loop() {
// Interrupt function trigger
unsigned long currentMillis = millis();
if (currentMillis - previousMinutes >= interval) {
previousMinutes = currentMillis;
interruptFunction();
 }
// Gas sensor value
gasConcentration = analogRead(gasSensorPin);
Serial.print(“Gas Concentration: ”);
Serial.println(gasConcentration);
 // Checking if the gas concentration exceeds the threshold
if (gasConcentration > gasThreshold && !gasDetected){

gasDetected = true;
Serial.println("**********Gas detected!**********");
Serial.println("Gas trigger routine started");
Serial.println("Buzzer, ventilation fan online!");
Serial.println("Valve closed");
gastrig_routine(); }
 // Checking if the gas concentration falls below the threshold
 if (gasConcentration <= gasThreshold && gasDetected)
```

```
 {
 gasDetected = false;
 Serial.println("****Gas concentration back to normal!****");
 gasnorm_routine(); } }
void interruptFunction() {
 // Routine for every 30 days
Serial.println("*********30 days have passed*********");
Serial.println("Conducting routine ventilation operation! ");
Serial.println("Banck to normal operation!");
 digitalWrite(redLedPin, HIGH);
 digitalWrite(motorPin, HIGH);
 delay(10000); // System on for 10 sec.
 digitalWrite(redLedPin, LOW);
 digitalWrite(motorPin, LOW);
 }
void gastrig_routine() {
 digitalWrite(redLedPin, HIGH);
 digitalWrite(greenLedPin, LOW);
 digitalWrite(motorPin, HIGH);
 // Rotate the servo to 90 degrees
 for (int i = 0; i <= pos; i++) {
 myservo.write(i);
 delay(20);
 }
 int sensorValue = analogRead(gasSensorPin);
 while (sensorValue >= gasThreshold) {
 digitalWrite(redLedPin, HIGH);
 tone(buzzerPin, 700, 100);
 delay(300);
 digitalWrite(redLedPin, LOW);
 delay(300);
 sensorValue = analogRead(gasSensorPin);
 }
 digitalWrite(redLedPin, LOW);
 digitalWrite(buzzerPin, LOW);
 }
void gasnorm_routine()
{
 digitalWrite(greenLedPin, HIGH);
```

```
digitalWrite(redLedPin, LOW);
digitalWrite(motorPin, LOW);
noTone(buzzerPin);
delay(100);
// Rotate the servo back to 0 degrees
for (int i = pos; i >= 0; i--)
{
myservo.write(i);
delay(20); }}
```

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