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Calibration Techniques for MQ Gas Sensors to Improve Gas Detection Accuracy (Review Article)

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Abstract

Sensors in environmental and agricultural monitoring systems are widely used due to their low-cost and ease of integration with microcontrollers and the Internet of Things (IoT). However, relying on real-time readings from these sensors can lead to inaccurate results due to their susceptibility to various environmental factors such as temperature, humidity, sensor age, and manufacturing variations between different units. Therefore, this research focus on calibrating a group of sensors, including the MQ-2, MQ-7, MQ-135, MQ-136, and MQ-137, with the aim of improving measurement accuracy and increasing the reliability of the resulting data. The calibration process involved determining the reference resistance (Ro) of each sensor under standard operating conditions, then calculating the resistance ratio (Rs/Ro) and using calibration curves derived from the technical data sheets to convert the electrical readings into actual gas concentration values. The sensors' responses to several target gases were evaluated. The results showed that applying calibration procedures significantly improved measurement accuracy and reduced the deviation between measured and reference values. It also contributed to increased sensor stability during continuous operation. The results further indicated that each sensor has different response characteristics, requiring specific calibration processes to achieve optimal performance. This study underscores the importance of initial and periodic calibration of MQ sensors before their deployment in practical applications to ensure reliable data for use in environmental monitoring systems, smart agriculture, and IoT applications.

Keywords: MQ sensors, MQ Calibration, ESP32, Internet of Things, air quality monitoring.

Introduction

Environmental parameters such as temperature, humidity, and gas levels directly affect human health, agriculture, and industrial specialties. Monitoring these factors in real time is considered necessary for detecting dangerous cases early hence making informed decisions [1]. Spatial coverage of low-cost sensors in the poultry house is critical for optimum monitoring of the microclimate [2] . In this article review, we discuss a low cost two types of data obtained from a network of sensors that are meshed with the storage online cloud through an ESP32 div module. The calibration enhanced the device readings in relation to the reference measurement in comparison to the not being calibrated [2]. CO2 can cause suffocation by displacing normal air in an enclosed perimeter. CO2 is considered to be heavier than air, hence it remains near the floor surface [3]. Among the by-product gasses of litter emissions, H2S is considered the riskiest gas. This gas is formed by the reduction of bacterial sulphide [4]. On the other hand, ammonia is also a main gas that is produced in the poultry house as a result of litter decomposing, especially old litter used for successive flock. Litter volatility depends mainly on pH, humidity level, ventilation rate, air velocity, and temperature. Alleviated levels of these pollutants not only risky to bird performance but also hazardous to the health of the workers. With the advancement of IOT technology real time of monitoring becomes feasible especially with the low-cost semiconductor sensors utilized with micro controllers NodeMcu ESP32 module. The sensors meshed with the controller unit are (MQ-137, MQ -135, and MQ -136). These sensors' output is a non-linear analog voltage related to gas concentration, an accurate calibration process was implemented to ensure the reliability of the microclimate data compared with other data from sensors that were not calibrated.

The Purpose of MQ Sensor Calibration

The calibration process for MQ sensors aims to improve the accuracy and reliability of gas concentration measurements by determining the true relationship between the sensor's output signal and the actual gas concentration. Calibration also seeks to calculate the sensor's reference resistance (Ro) under standard conditions, minimize the influence of environmental factors such as temperature and humidity, and compensate for manufacturing variations between different sensors. Furthermore, calibration helps reduce measurement errors and improve performance stability over time, ensuring more accurate and reliable data for applications such as air quality monitoring, gas concentration detection, and IoT-enabled agricultural systems.

Calibration

MQ calibration is considered to be among the most important steps to ensure the precision of measurement that results in enhancing reliability in using these type of sensors when detecting the concentrations of gases .In general, the MQ sensors depends on the internal resistance change during exposed to different levels of gases such as Carbone monoxide , Carbone oxide ,Ammonia and Methane along with other different gases that could be generated in the poultry houses precisely. The readings for these sensors are inaccurate if it wasn't for the calibration, especially in the first 24 hr. of operation, due to the subjection of environmental factors in addition to the diversity of manufacturing destinations.

The neglect of MQ sensors calibration may lead to misreading's of the measurements, which results negatively in the proficiency of the reliability, especially in the safety systems, air monitoring, and the agricultural projects that deal with air quality such as the mini climate in poultry houses. The calibration of sensors in general, MQ in particularly is indispensable for getting steady and reliable readings for different applications [5].

The low-cost MQ gas sensors gained an increasing interest in the recent years for the easiness of use in different applications, such as intelligent monitoring systems and air quality detection units. The primary challenge in MQ sensors is represented in the precise measurement through the accurate calibration that results in getting a correct quantification [6] [7].

The studies on gas detections refer that the proficiency of gas sensors depends on some features such as selection, consistency of readings, and sensitivity hence, these characteristics is impacted by calibration [8].

The MQ sensors suffer from essential issues such as poor selectivity and getting impacted by environmental factors thus making calibration an imperative step toward enhancing the quantification (measurement) [9].

The modern studies focus on calibration properly for these kinds of sensors whereby studies inferred that calibration depends on correlating an equation between the sensor resistance and the gas concentration; this is conducted using linear regression and logarithm to transform the readings into ppm [9].

An investigation referred to studying the calibration period resulted in the saying that selection of the modeling plays an imperative role in obtaining precise data that resulted in enhancing the calibration practically [10].

Artificial learning is considered among the methods used widely to process the problems presented in calibration and improving the calibration, hence the performance of the sensors [11].

MQ sensors suffer from time-lapse bias, where sensor characteristics change over time, leading to unreliable measurements. This necessitates recalibration and the use of a corrective model to maintain measurement accuracy. In general, the calibration process of MQ sensors represents an essential step to ensure the precision of data readings [12].

Calibration Method

1- The sensors are powered on; the power supply is 5V. The functioning period is 24-48 hr. before calibration to ensure stability prior to calibration to, stabilize the sensing element, moreover decreasing the driftage in signal
2- After the heating process for sensors the sensors, are placed in clean air to calculate resistance reference point in the clean air.
3- The sensor resistance is calculated in the detecting environment through the following equation
   $Rs=(VCC_{sv}\text{-}Vout/vout)*RL$
   VCC= the supplied voltage
   Vout: the quantifies sensor voltage
   RL: 10 Kilo ohm
4- The resistance standpoint Ro is calculated through the following equation $Ro= Rs/ \lambda$
   = a constant in the data sheet is relevant to every individual element
5- The accuracy checking is done by using a reliable gas detector

followed by recalibration until reaching a good precision.

Materials and Methods

MQ 136 gas sensor

The MQ-136 gas sensor (figure 2) can be used for detecting hydrogen sulfide (H_2S) and related sulphur gases. It belongs to the Metal Oxide Semiconductor (MOS) family of sensors. They utilize electrical resistance of tin oxide (SnO_2) semiconductor technology. That electrical resistance of which changes when exposed to the target gas. The conductivity of the sensor conductor is low in clean air, but as the concentration of hydrogen sulphide increases, the sensor's output voltage changes, which a meshed microcontroller can detect and translate into digital data. The sensor exhibits good sensitivity to H_2S within a measurement range of approximately 1–200 parts per million (ppm) and operating at a 5 V voltage. It has an inbuilt heating component to maintain all the system running at best conditions. The sensor's analogue output is connected to a control unit to read changes in gas concentration and transmit the data to a monitoring and analysis system.

Several other gases that contains N in its compositions can be detected too.

1. Ammonia (NH_3): Why it can trigger the sensor: Ammonia is a strong reducing gas. When touching the heated element of SnO_2 surface of the MQ-136, the Ammonia releases electrons and reduces the electrical resistance of the heated element during interacting with the oxygen ions that deposited on the surface of the conductor.

   When the MQ-136 sensor is connected to one of the analog input ports (ADC) on the ESP32 module unit, the voltage output from the sensor is continuously quantified. Afterward the analogue signal is converted to reasonable digital values by calibrated processed software to calculate the relative change in gas concentration to monitor air quality within the studied environment.
2. **Nitrogen Dioxide (NO_2) / Nitric Oxide (NO) :**

Unlike Ammonia, NO_2 is a strong oxidizing gas. Instead of decreasing the resistance, it usually confides electrons and increases the electrical resistance of the sensor.in other words: While it results in a reversed electrical reaction compared to H_2S, it still alters the sensor's baseline data.

3- Hydrogen Cyanide (HCN)

HCN is another oxidising gas containing nitrogen that shows cross-sensitivity with many hazardous gas sensors designed for H2S, despite being extremely poisonous and uncommon in casual settings.

The MQ-2 gas sensor

It is also considered a metal oxide semiconductor (MOS) sensor (figure2), operates on the principle of change in the resistance of a tin oxide semiconductor layer when exposed to flammable gases. These changes results in an electrical signal proportional to the gas concentration in the surrounding environment.

The sensor is highly sensitive to hydrogen, methane, propane, butane, natural gas, and smoke gases. Operating at 5 volts, the sensor contains an internal heating element within to maintain the temperature required for sensing and detecting.

The sensor is connected to an ESP32 module via an analog input to measure and process the output signal, and then transmit the data to a cloud-based monitoring system and analysis for real-time air quality analysis and tracking of environmental changes.

Meshing with ESP32 NodeMcu

MQ gas sensors can be integrated with Systems such as NodeMCU ESP32 units to create an IoT-based environmental monitoring system capable of transmitting gas concentration data to cloud platforms such as Google Cloud or Blynk [13]. The ESP32 unit serves as the main microcontroller that reads analog signals from MQ sensors, processes the data, and sends it wirelessly through Wi-Fi connectivity [14]

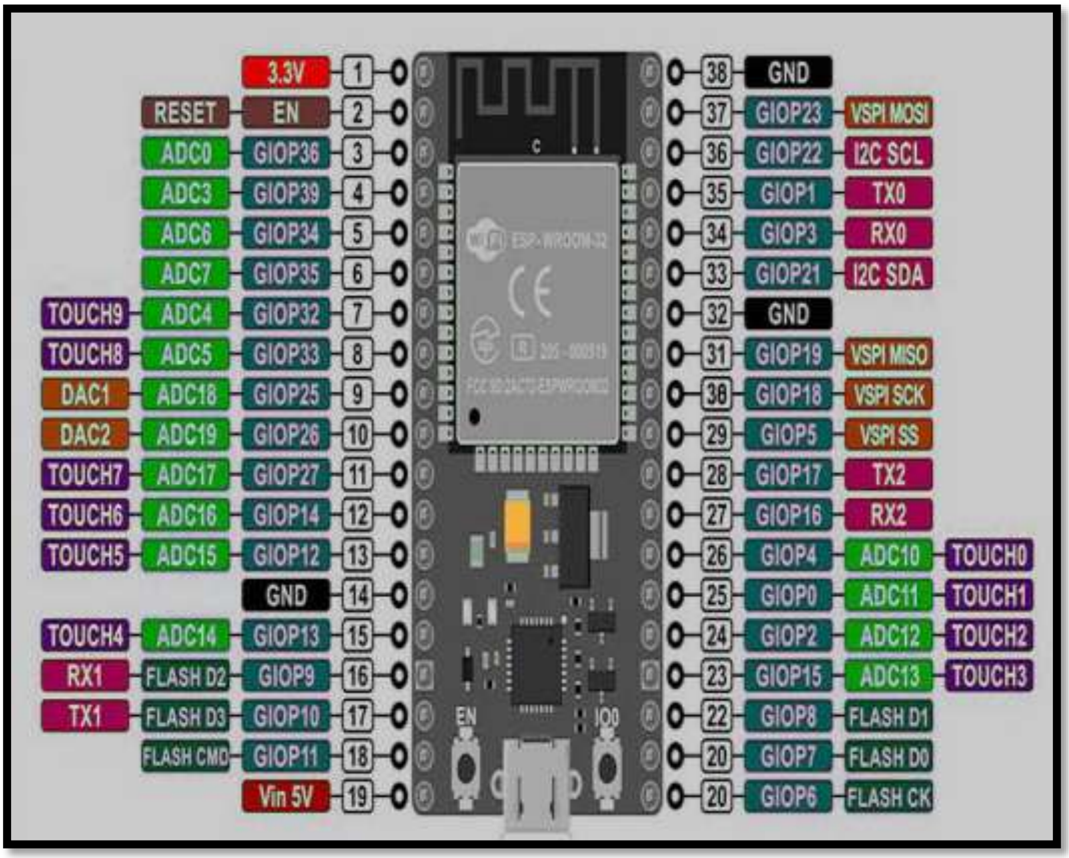
The meshing process begins by connecting the MQ sensor output pin to one of the ESP32 unit analog input pins (ADC). Since MQ sensors produce An analog voltage that is proportional to gas concentration, the ESP32 converts this voltage into digital values. The sensor readings are then calibrated to determine the sensor resistance (Rs) and estimate gas concentration in parts per million (ppm). [15]

Typical hardware connections include:

MQ sensor VCC → ESP32 5V or VIN

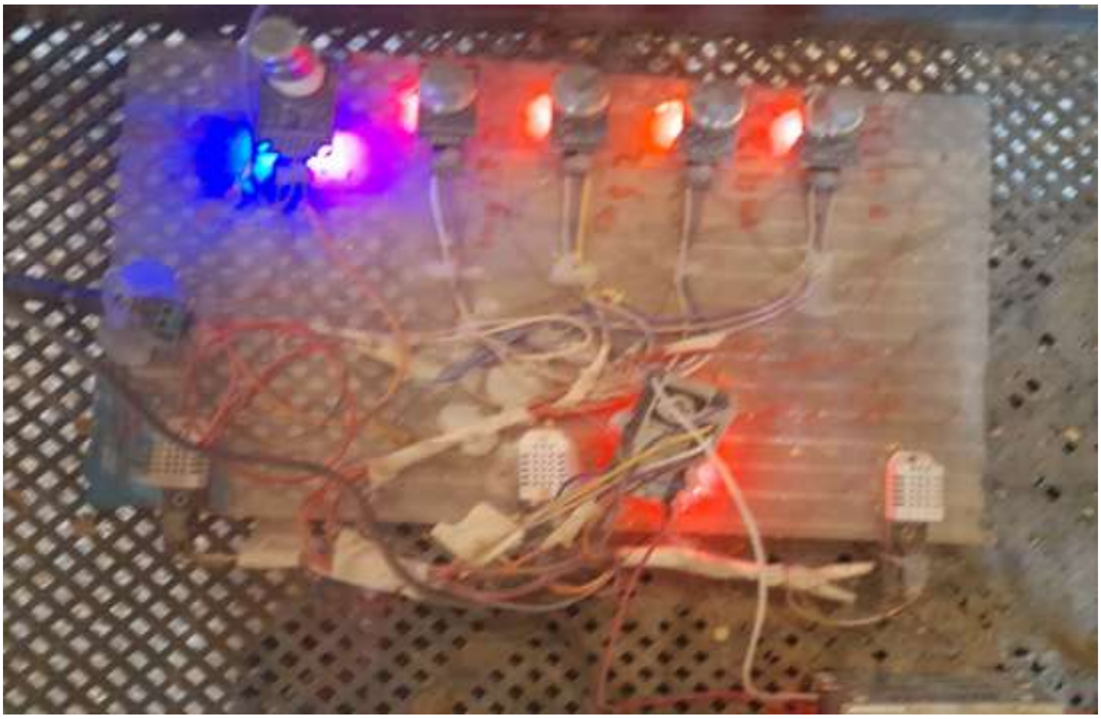
MQ sensor GND → ESP32 GND

MQ sensor AO (Analog Output) → ESP32 ADC pin (e.g., GPIO34)



(Figure 1) Esp32 board Cited from [16]

(Figure 2) Dht 22 temperature and humidity sensor and MQ sensors



(Figure 3) Sensors working during Calibration in fresh air

(Figure 4) Sensors working in the poultry house (contaminated microclimate with pollutants)

(Table 1) Google Sheet Code

```
function doGet(e) {
   var sheet = SpreadsheetApp.openById('1cyVQVoiw-
aoXjmgOi0ULA3OkX3XjCoeWw50E0IiwWEY').getActiveSheet();
      // Extract individual parameters instead of assuming they are comma-separated
   var value1 = e.parameter.value1;
   var value2 = e.parameter.value2;
   var value3 = e.parameter.value3;
   var value4 = e.parameter.value4;
   var value5 = e.parameter.value5;
   var value6 = e.parameter.value6;
    // Create an array with the current date and the extracted values
   var row = [new Date(), value1, value2, value3, value4, value5, value6];
      // Append the row to the sheet
   sheet.appendRow(row);
    return ContentService.createTextOutput("Success");
}
```

Arduino Code (Table 2)

```
#include <WiFi.h>
#include <DHT.h>
#include <Adafruit_Sensor.h>
#include <HTTPClient.h>

const char* ssid = "Asiacell-4G-C7BA";
const char* password = "58501849";
const char* googleScriptURL =
"https://script.google.com/macros/s/AKfycbxh
e5IQQPlKZwdJMuQKdTEl-
Or1rYtTIiPHPojWgBFBTU9vPEGMYvorM0KJ
mLXh7AFG/exec";

//define pin data
#define DHT1PIN 14
#define DHT1TYPE DHT22
DHT dht1(DHT1PIN, DHT1TYPE);
int h1;
int t1;

#define DHT2PIN 27
#define DHT2TYPE DHT22
DHT dht2(DHT2PIN, DHT2TYPE);
int h2;
int t2;

#define DHT3PIN 18
#define DHT3TYPE DHT22
DHT dht3(DHT3PIN, DHT3TYPE);
int h3;
int t3;

void setup() {
  Serial.begin(115200); //1bit=10µs
  WiFi.begin(ssid, password);
    while (WiFi.status() != WL_CONNECTED)
{
        delay(1000);
        Serial.println("Connecting...");}
```

```
 dht1.begin();
 dht2.begin();
 dht3.begin();
 pinMode(DHT1PIN, INPUT);
 pinMode(DHT2PIN, INPUT);
 pinMode(DHT3PIN, INPUT);
}

void loop() {
  h1 = dht1.readHumidity();
  t1 = dht1.readTemperature();
  h2 = dht2.readHumidity();
  t2 = dht2.readTemperature();
  h3 = dht3.readHumidity();
  t3 = dht3.readTemperature();

String url = String(googleScriptURL) +
"?value1=" + String(h1) + "&value2=" +
String(t1) + "&value3=" + String(h2) +
"&value4=" + String(t2) + "&value5=" +
String(h3) + "&value6=" + String(t3);

    HTTPClient http;
    http.begin(url);
    int httpResponseCode = http.GET();
    http.end();

    Serial.print("h1:");
    Serial.println(h1);
    Serial.print("t1:");
    Serial.println(t1);
    Serial.print("h2:");
    Serial.println(h2);
    Serial.print("t2:");
    Serial.println(t2);
    Serial.print("h3:");
    Serial.println(h3);
    Serial.print("t3:");
    Serial.println(t3);
         delay(500); //

}
```

Conclusions

This process is done to ensure turning the voltage into resistance accurately hence calculating a correct standpoint that results in enhancing the detection of gas concentration in the barn.

This process is performed and done to ensure the accurate and precise conversion of voltage into resistance, thereby enabling the precise calculation of sensor readings and improving the reliability of gas concentration detection inside the barn.

Thus, Proper calibration and signal processing of MQ sensors could help minimize measurement errors, reduce the influence of environmental variations such as temperature and humidity, resulting in improving sensor sensitivity and stability during operation.

In addition to that, this procedure contributes to enhancing overall monitoring performance, which is essential for maintaining suitable and appropriate environmental conditions, leading to enhancing better air quality assessment in poultry and livestock houses alike.

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