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Calibration of MQ-7 and Detection of Hazardous Carbon Mono-oxide Concentration in Test Canister

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Abstract: The most active research in recent years is estimating the noxious waste which has a very high influence on the human health. There are many gases which have adverse effects on human health. Here carbon monoxide (CO) is considered as one of toxic gas which is considered to cause various health issues based on the concentration the casualty is exposed. In this paper, we ensure the presence of hazardous gases and also provide the procedure to estimate the concentration of the same with the help of the MQ-7 sensor and test setup. The calibration of the sensor is carried out with a canister of known volume and the estimation of the CO in the test environment is also determined.

Keywords: Calibration; MQ-7; Hazardous Gases.

I. INTRODUCTION

Many circumstances [3], test experiments lead to the production of gases and vapours directly or indirectly. These gases and vapours are classified in to different levels of hazardousness and toxicity [10] [11]. Those hazardous and toxic gases when inhaled or exposed to humans have harmful effects. There are gases that become dangerous to health in concentrations as little as 1ppm (parts per million). Workers are at high risks to these gases which causes various health aliments depending on the duration of the gases they are exposed too. Hydrogen sulphide has a bad odour at 0.1ppm but leads to paralysis when exposed to the concentration over 50ppm. This does not strictly suggest that 50ppm is the hazardous limit but even if the concentration is slightly below than the hazardous level may lead to paralysis or death when exposed to longer durations. Various other gases like Ammonia, carbon dioxide, carbon monoxide, Methane have their own characteristics. Ammonia has a threshold limit of 25ppm whereas 500 ppm is immediately dangerous to life. Carbon dioxide produced by combustion, fermentation, brewing methods has a maximum safe level of 5000ppm beyond which may cause severity in health issues. Carbon monoxide (CO) is a class-III toxic gas which is slightly less dense than air and it is a colourless gas with neutral odour and also tasteless. This gas can readily mix with air and can be readily inhaled. There are many cases of carbon monoxide poisoning reported in many countries [5]. The threshold limit is 25ppm and when the concentration is 1200ppm and greater leads to a very high risk for life.

In this paper, we determine the concentration of the carbon monoxide gas in the test environment and also calibrate the sensor to read the amount of CO present in the canister. Calibration is the process of configuring an instrument to provide a result for a sample within an acceptable range [6] [7]. The accuracy of the instrument is maintained or altered according to requirements by calibrating the instrument. The main operation of calibrating [8] [9] the device is to eradicate and minimize the factors that cause imprecise measurements. The procedure for calibrating devices may vary but generally, it involves using the instrument to test samples for various values. These values from the test samples are called as "**calibrators**". Calibrations are performed using calibrators to establish a complement at specific points within the instrument's operating range. On a practical aspect, a settlement must be made between the desired level of product performance and the effort correlated to conclude the calibration.

II. TYPES OF GAS SENSORS

There are different type of gas sensors [1] and various procedures [2] to detect gases are available in market

Electrochemical Sensors.
Catalytic Bead Sensors.
Infrared Sensors.
PID Sensors.
Thermal Conductivity.
Flame Ionisation Detector (FID)
Metal Oxide Sensors (MOS)

A. Electrochemical Sensors

Electrochemical sensors are compact, consume less power and have a long life span which is mostly preferred to determine and measure the specific toxic gases at the PPM level. It operates at a temperature ranging between -20° to +50°C.

B. Metal Oxide Sensors

Metal oxide sensors are low cost used to detect toxic, chlorinated solvents and combustible gases. It is mostly preferred in environments where the atmospheric hazards are not known. The limitation of the sensor is accuracy and the operating range since the sensor output varies logarithmically with respect to the concentration of the gas.

C. Thermal Conductivity Sensors

Thermal conductivity sensors which are preferred to determine solvent vapour in air and gas leaks of of a combustible gas expressed in % LEL (Lower explosive limit) basically consist of the wired coil. The sensor operates at a very high temperature of 250°C which is transferred to the surrounding gas. Depending on the thermal conductivity of the gases the amount of the heat transferred varies.

There are different varieties of gas sensors available to measure the concentration of Carbon monoxide. They are an electrochemical sensor, semiconductor, MEMS carbon monoxide sensor etc. Here in this paper, we use a semiconductor sensor MQ-7 to detect the concentration of carbon monoxide in the test environment.

III. VARIOUS CALIBRATION PROCEDURES

A. External Calibration

•Signal is proportional to concentration -established using externally prepared standards
•Assumes that the sensitivity (signal/conc.) is the same for samples and standards
•Assumes that the signal arises only from the analytic most cases
•Does not account for **s**ample matri**x** or instrumental drift.

B. Standard Addition

•Known amounts of analyte are added to aliquots of sample
•Signals are measured as a function of concentration added.
•Accounts for **s**ample matrix, but not for instrumental drift.

C. Internal Addition

• A substance is known as an "internal standard" is added to samples and standards (chemically similar to the analyte).
• Used to correct for drift (changes in sensitivity over time) and matrix effects (sample-related changes in sensitivity).

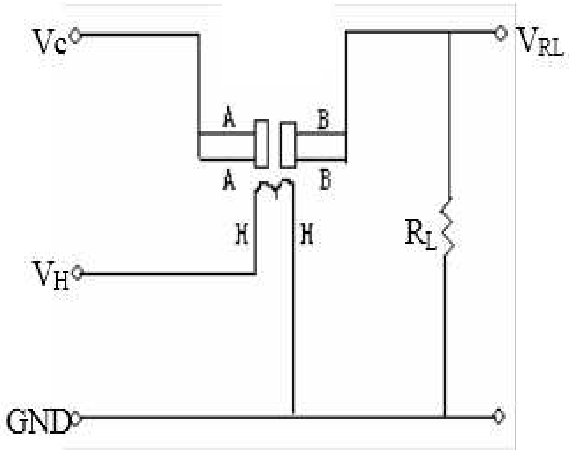
IV. PROPOSED SYSTEM

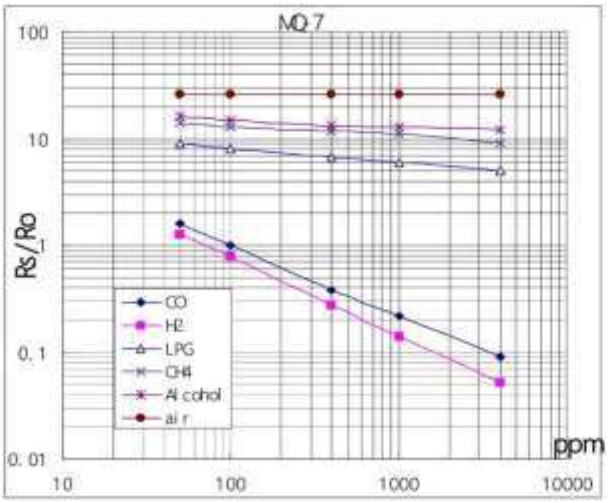
A. Calibration of MQ-7 sensor

The MQ series gas sensors are resistive chemical sensors. These sensors make use of small resistances and thus gets a higher flow of current, getting a noticeable amount of heat which is used to burn the air to give an analogue reading. All the MQ series gas sensors require being calibrated. The purpose of this calibration process is to determine a base value that can be found in the clean air. This base value is used in order to determine PPM value of another scenario. These sensors are non-linear and therefore they require to be calibrated accurately. Without proper calibration, the interpretation of raw analogue reading of the sensor is meaningless.

B. Basic Calibration

The basic measuring circuit is shown below,





(a) (b)

Fig 1(a) Calibration Circuit **(b) PPM versus Rs/Ro**

Vc is the circuit voltage which is applied to the sensing resistance (Rs) and the load resistance (RL), Vrl is the voltage across the load resistance which is obtained from the sensor output. The data sheet [4] of the carbon monoxide sensor (MQ-7) provides a typical output curve of Rs/Ro vs. gas concentration in PPM as shown in figure 1.

The CO concentration is a non-linear function of the normalized ratio which is defined as Rs/Ro. Where Rs is the measured sensor resistance and Ro is the sensor resistance at 100ppm of CO. Without considering the influences of temperature and humidity, the characteristic curve can be used to obtain a concentration of CO in PPM. The curve is approximated with a straight line to extract the following equation which describes the Carbon monoxide concentration in PPM.

The sensor resistance Rs can be calculated by voltage divider from the following equation,

$$Rs=((V_C-V_{RL})/V_{RL})*RL$$

The load resistance RL can be adjusted to allow the sensor to obtain the full range of values. For the CO sensor, we use RL=10000 Ohms.

C. Flowchart

A flowchart is a visual representation of steps and decisions that are required to carry out a process. The consecutive steps are represented by the arrows that are directed towards. Figure 2 describes the sequential procedure that is involved in measuring the concentration of carbon-monoxide gas in the canister.

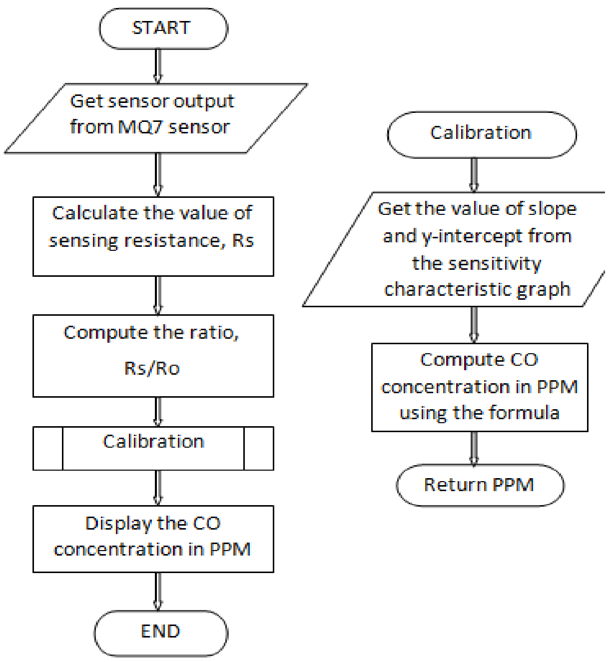


Fig 2: Flow Chart of Calibration

V. HARDWARE

A. **Raspberry Pi**

The basic features of the Raspberry pi are listed below:

SoC: The system on chip specification of the raspberry pi is Broadcom BCM2837.The other important specifications of the system are as follows:

CPU: 4× ARM Cortex-A53, 1.2 GHz.

GPU: Broadcom Video Core IV.

RAM: 1GB LPDDR2 (900MHZ).

Networking: 10/100 Ethernet, 2.4GHz 802.11n wireless

Bluetooth: Bluetooth 4.1 Classic, Bluetooth Low Energy

Storage: microSD

GPIO: 40-pinheader, populated.

Ports: HDMI, 3.5mm analogue audio-video jack, 4× USB 2.0, Ethernet, Camera Serial Interface (CSI), Display Serial Interface (DSI).

Wireless Radio: The Broadcom BCM43438 chip provides 2.4GHz 802.11n wireless LAN, Bluetooth Low Energy, and Bluetooth

4.1 Classic Radio Support

Antennas: There's no need to connect an external antenna to the Raspberry Pi 3.Its radios are connected to this chip antenna soldered directly to the board.

System-on-chip (SoC): The Broadcom BCM2837 system-on-chip (SoC) includes four high-performance ARM Cortex-A53 processing cores running at 1.2GHz with 32kB Level 1 and 512kB Level 2 cache memory, a Video Core IV graphics processor. This is also linked to a 1GB LPDDR2 memory module on the rear of the board.

GPIO: Raspberry Pi 3 has 40 GPIO pins, these pins will work without any modification.

USB Chip: The Raspberry Pi 3 has SMSC LAN9514 chip. Raspberry Pi is a less expensive computer based system

B.Mq-7 Gas Sensor

The semiconductor Carbon mono-oxide gas sensor is suitable for sensing CO concentrations in the air. The MQ-7 can detect CO-gas concentrations ranging from 20 to 2000ppm.This sensor has a high sensitivity and fast response time. The drive circuit is very simple but there is a need to power the heater coil with 5V, add a load resistance, and connect the output to an ADC (Analog to Digital Converter). The sensitive material used in the MQ-7 sensor is Sno2 (Stannum oxide) which possess lower conductivity in clean air. The detection of carbon monoxide in the clear air will be done by cycle high and low temperature method to detect CO at low temperatures.

C.MCP 3008

The MCP3008 is a 10-bit ADC which uses successive approximation method with the on-board sample and hold circuit. The MCP3008 has programmable analogue inputs as pseudo-differential input pairs or single-ended. Differential Nonlinearity (DNL) and Integral Nonlinearity (INL) are specified at +/-1 LSB. Communication with other devices is accomplished using a simple serial interface compatible with the SPI protocol. The device is capable of conversion rates of up to 200 ksps. The MCP3008 operate over a broad voltage range (2.7V – 5.5V). Low-current design permits operation with typical standby currents of only 5 nA and typical active currents of 320 µA. The MCP3008 is offered in 16-pin PDIP and SOIC packages.

VI. SYSTEM BLOCK DIAGRAM

The Block diagram of the system built for experimenting is shown in figure 3.

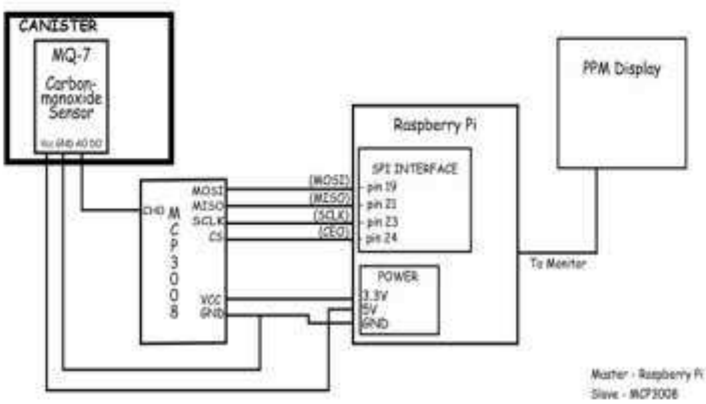


Fig 3: System Block Diagram

The System block diagram consists of a Raspberry pi which is connected to the MQ7 gas sensor through an ADC MCP3008. The gas sensor is attached to the canister where the gas is measured. The measured gas is displayed on the LCD in ppm.

VII. CALIBRATION / TESTING

The setup of the calibration process consists mainly of a Raspberry pi, MQ-7 sensor. The carbon mono-oxide gas sensor is ensuite with a small canister of considerable volume as shown in the block diagram. The setup is made sure that there is no leakage and is carried out in a suitable environment.

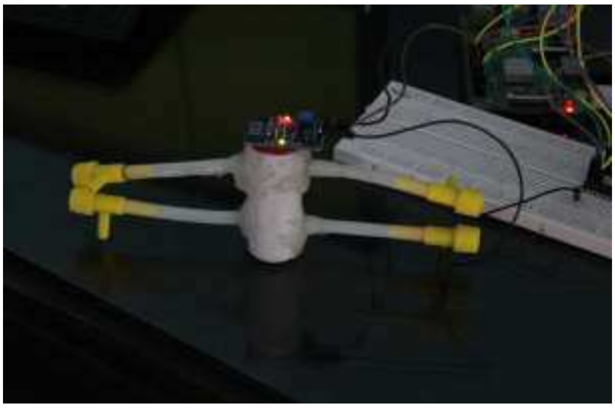


Fig 4: CO Sensor Connected to Canister

The canister used that is considered is given with a suitable number of inlets and outlets at appropriate positions for the movement of the gas. The calibration is carried out in a small canister which has a volume of about 28.05cc. The canister consists of four valves through which the gas can be pumped in and out. The canister is shown in figure 4.

The carbon mono-oxide gas is pumped into the canister, through one of the valves by shutting down the remaining valves. As the gas is pumped in to the canister the sensor detects it and measures the concentration of the gas.

The output values that are obtained are of analogue values, these values are converted into PPM values by calibration using respective mathematical conversions which are displayed on the screen. The sufficient amount of gas is injected in to the canister and all the valves are locked.

The figure 5 show how the carbon-monoxide gas is pumped in to the test setup.

Fig 5: CO Pumped to Canister

As the MQ-7 sensor can detect the CO gas in the range of 20 - 2000 ppm. When the gas is within the range, the calibrated values are displayed on the screen. The calibration values will always be in the range of the sensor pre-specified by the manufacturer. If the concentration is beyond the calibration range the sensor pops up an out of range message on the screen. In order to bring back the gas to the measuring range of the sensor one of the valve is slowly opened so that the gas starts to leak out.

Fig 6: Displaying the concentration of Carbon monoxide

Once the concentration is well within the range of the sensor the ppm value is displayed. A set of values is measured by the sensor by slowly opening the valves. The readings are tabulated as shown below. The concentration in ppm is calculated wirt respect to the volume of the container used for the test. The gas of 1cc in 1000cc container in terms of ppm is defined by

$$C_{ppm} = (1/1000) * 10^6 = 1000ppm$$

In this setup, the canister used has a volume of 28.05cc the amount of concentration of gas present inside the canister is measured by the sensor that determines the ppm level. As the valves are opened the CO gas filled inside the canister is diluted with the air and the sensor measures the content of the CO gas at different concentrations and displays on the screen. The table shows the ppm value for different levels of CO concentration in the canister

Table 1: Concentration of Co Gas Measured

Sl. No	**Concentration of CO in canister(volume=28.05cc)**	**Calibrated CO (PPM Level)**
1	0.03721	1326.9015
2	0.02527	901.1568
3	0.01476	526.2650
4	0.00605	215.7585
5	0.003521	125.5551
6	0.001493	53.2547
7	0.00059	21.0483
8	0.00057	2.0348
9	0.00053	1.9021

The calibration procedure is described in the flowchart and the readings are tabulated for the same. The sensor on test measures the presence of the CO gas in the canister for different concentrations

VIII. CONCLUSION

Calibration of gas sensors using calibrating equipment is more expensive. A simple procedure for calibrating gas sensors is discussed in this paper where the value of sensing resistance is computed and the ratio of RS/Ro is calculated which is later used in the code to determine the value of the gas in PPM. The paper restricts to calibration of an MQ-7 sensor which can be later deployed for various application where the detection of CO gas is required. There are other calibration procedures involving temperature and humidity which may give precise results with a compromise of increasing complexity.

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