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LOW-BUDGET MEASURING DEVICE FOR DETERMINING CARBON DIOXIDE LEVELS IN INDOOR SPACES

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Abstract: *Nowadays, when it comes to measuring indoor air quality, the most common topic of discussion is the impact of PM particles on human health. However, in indoor environments, the impact of some gases on human health is more significant than the impact of PM particles. Very often, VOC (volatile organic compound) measurement is declared sufficient to detect indoor air quality, which is not entirely accurate. The meaning of VOC measurement is often misunderstood. For exmaple, CO_2 sensors and VOC sensors measure very different things. CO_2 and VOC are two critical components in air quality that can significantly impact human health and comfort. CO_2 is a naturally occurring gas primarily produced by human respiration and combustion processes. While it is harmless in small quantities, elevated levels in enclosed spaces can lead to drowsiness, decreased cognitive function, and long-term health concerns. VOCs, on the other hand, are a group of chemicals released into the air from various sources, such as cleaning products, paints, and building materials. These compounds can have adverse effects ranging from mild irritation to more severe conditions like respiratory issues, headaches, and even long-term chronic illnesses when exposure is prolonged. In this paper, we focus on the impacts of CO_2 on human health and ways to efficiently and inexpensively measure CO_2 levels.*

Keywords: *CO_2, Sensors, MCU, VOC, Air Quality Monitor.*

1. INTRODUCTION

First, we will give a brief overview of what CO_2 (carbon dioxide) is. Carbon dioxide molecules are very small, with only one carbon atom and two oxygen atoms forming the whole molecule. Even though carbon dioxide is a common gas, it makes up less than 1% of the atmosphere. Outdoor CO_2 levels tend to average around 420 ppm, the levels indoors can increase far beyond that, upwards of 2000 ppm or even 3000 ppm [1].

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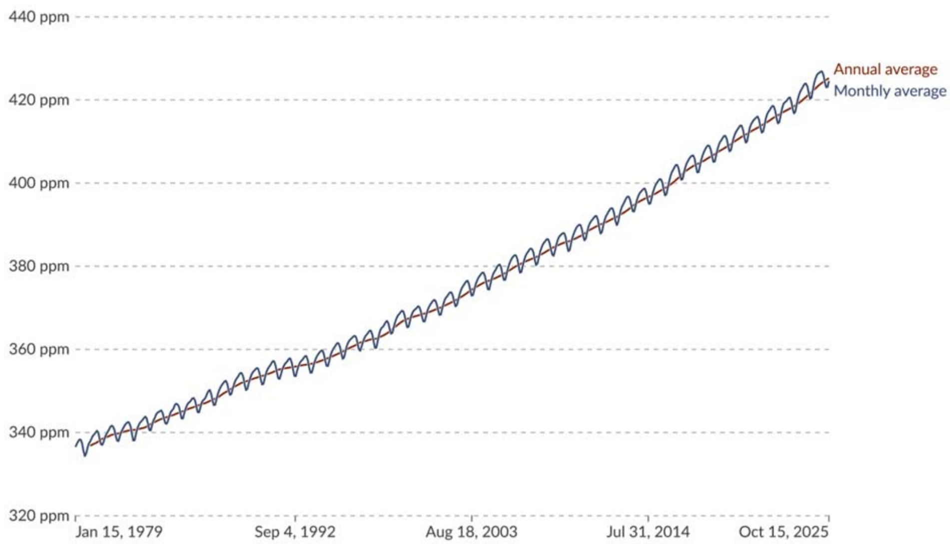

Fig. 1. Global atmospheric CO_2 concentration, Data source: NOAA Global Monitoring Laboratory - Trends in Atmospheric Carbon Dioxide (2026)

CO_2 plays a key role in the environmental phenomenon known as the greenhouse effect. Because of its close relationship with global warming, this aspect is of great importance in regulating the temperature of the planet. CO_2, along with other greenhouse gases such as methane, ozone and nitrous oxide, is released into the air. It traps heat from the sun in the Earth's atmosphere, causing global temperatures to rise gradually. Of all the gases that contribute to the greenhouse effect, CO_2 is the most naturally occurring. Its concentration in the atmosphere has increased dramatically in recent decades as a result of human activity (Fig.1). Among these gases, carbon dioxide stands out because it remains in the atmosphere for decades.

At normal levels, CO_2 is non-toxic to humans and plays a main role in regulating blood pH, respiration and blood pressure. Exposure to elevated levels of CO_2 can cause harmful effects such as headaches, dizziness, muscle cramps, respiratory and cardiovascular problems, even loss of consciousness and, in extreme cases, death by asphyxiation [2].

What specifically inspired us to embark on creating a low-budget CO_2 measuring sensor? During classes, especially in the afternoon, teachers often notice drowsiness, lack of focus, yawning, and lack of concentration among students. Many studies have proven that high levels of carbon dioxide are the cause of this.

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2. HARDWARE

The main component for measuring CO_2 levels that we used is sensor from Winsen MH-Z19B, small size sensor, using non-dispersive infrared (NDIR) principle to detect the existence of CO_2 in the air, with good selectivity, non-oxygen dependent and long life.

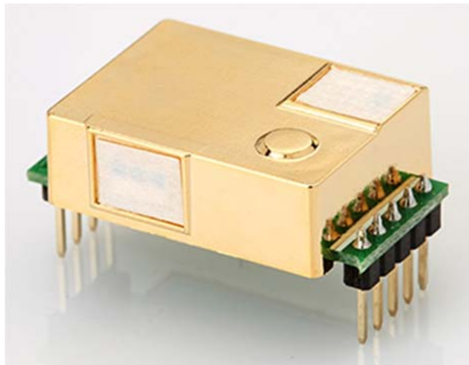

Fig. 2. Winsen CO_2 sensor, MH-Z19B

NDIR or Non-dispersive infrared CO_2 sensors are the standard worldwide due to their long life-span, low power requirements, speed, and most importantly, low cross-sensitivity to other gases in the sample.

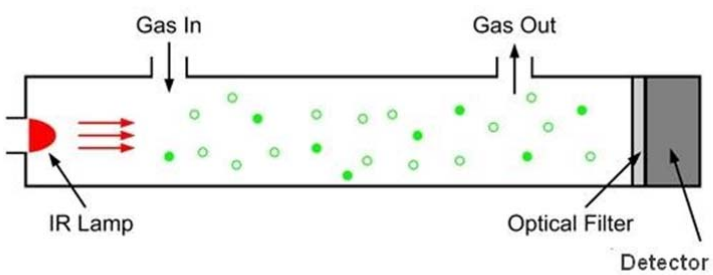

Fig. 3. NDIR [3]

An NDIR CO_2 sensor works by measuring infrared light in an air sample. The amount of infrared light absorbed by the molecules of carbon dioxide is proportional to the number of CO_2 molecules. This allows the sensor to measure the amount of CO_2 by volume in an air sample inside the sensor.

The CO_2 sensor must warm up for about 3 minutes to start measuring accurately.

The system is based on ESP32, a low-cost, low-power system on a chip (SoC) microcontroller with integrated Wi-Fi and Bluetooth, designed by Espressif Systems for Internet of Things (IoT) applications. The original ESP32 chip had a single core Tensilica Xtensa LX6 microprocessor. The processor had a clock rate of over 240 MHz, which made for a relatively high data processing speed. Two basic models are available, ESP32-C and S series, which include both single and dual core variations. These two series also rely on a Risc-V CPU model instead of Xtensa. Risc-V is similar to the ARM architecture, which is well-supported and well-known, but Risc-V is open source and easy to use. Specifically, Risc-V and ARM have good support from GNU compilers, while the Xtensa needed extra support and development to work with the compilers.

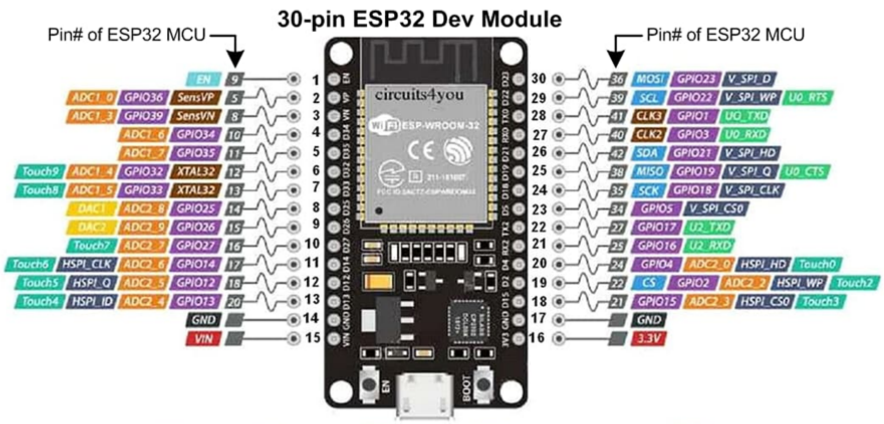

Fig. 4. ESP32 from Espressif Systems

Data visualization is performed with Mini OLED display 0.96 inch 128x64 with I2C communication protocol. The sensor node is battery-powered for mobile use. As a programming environment we used Arduino IDE. The code consists of several program units such as a library for working with the CO_2 sensor and a library for working with OLED display. The only problem with the hardware solution is that the EPS32 controller operates at 3.3V and the CO_2 sensor has an operating voltage of 5V. To solve this, we use XL6009 Boost Converter, DC-DC Adjustable Step-Up Voltage Regulator from 3-30V to 5-35V on 400KHz.

Fig. 5. OLED display 0.96 inch 128x64

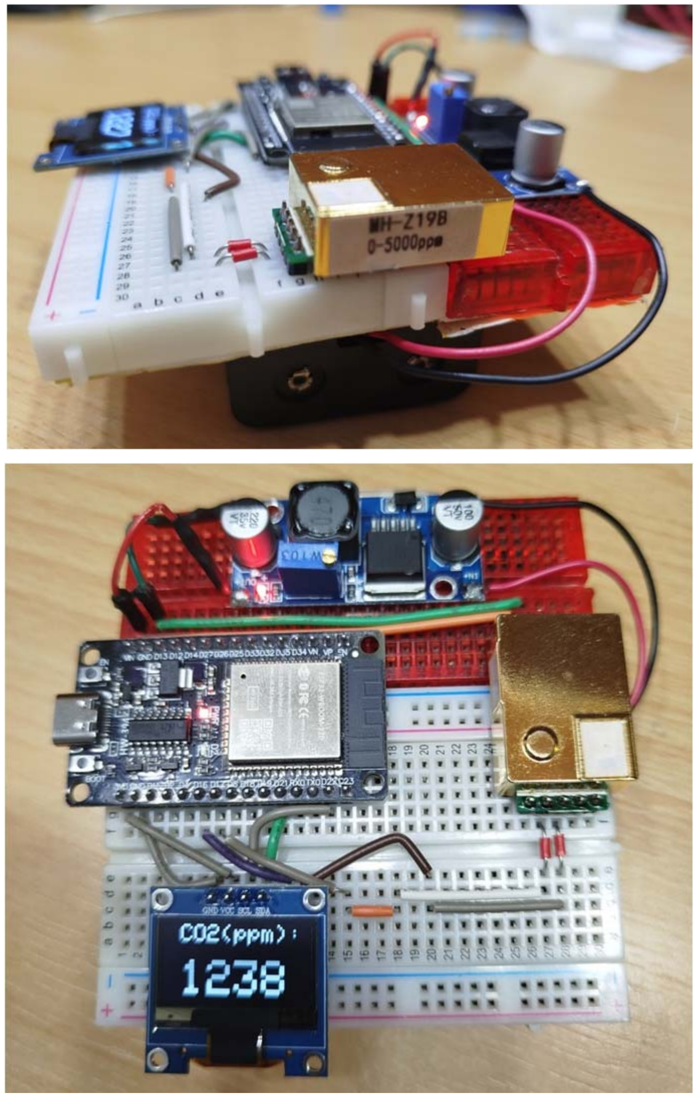

Fig. 6. Realistic view of the sensor node

3. SOFTWARE

The complete working code, ready for upload, is attached.

```
#include <MHZ19.h>
#include <Adafruit_GFX.h>
#include <Adafruit_SSD1306.h>

#define SDA_PIN 1
#define SCL_PIN 2
#define RXD1 6
#define TXD1 7
```

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```
Adafruit_SSD1306 display(SCREEN_WIDTH, SCREEN_HEIGHT, &Wire);
MHZ19 mhz(&Serial1);

void setup(){
  Serial.begin(115200);
  Serial.println(F("Starting..."));
// Initialize Serial1
  Serial.begin(9600, SERIAL_8N1, RXD, TXD);
  Wire.begin(SDA_PIN, SCL_PIN);
  display.begin(SSD1306_SWITCHCAPVCC, 0x33);
  display.clearDisplay();
  display.display();
}

void loop(){
  display.clearDisplay();
  display.setTextSize(2); // Draw 2X-scale text
  display.setTextColor(SSD1306_WHITE);
  display.setCursor(15, 0);

  MHZ19_RESULT response = mhz.retrieveData();
  if (response == MHZ19_RESULT_OK){
    Serial.println(F("CO2: "));
    Serial.print(mhz.getCO2());
    Serial.println(F(" ppm"));
    display.println(F("CO2(ppm):"));
    display.println();
    display.setTextSize(4);
    display.setCursor(15, 30);
    display.print(mhz.getCO2());
    display.display();      // Show initial text
    delay(100);
  }
  else  {
    Serial.print(F("Error, code: "));
    Serial.println(response);
  }
    delay(5000);
}
```

4. CONCLUSION

The goal of this paper was to show that there is a possibility of creating a low-budget CO_2 measuring node that, although low-cost, also has high measurement accuracy. To compare the measurement results, we used a professional carbon dioxide sensor from the Sensirion company and we achieving accuracy in measurements of +/- 1%.

The measuring results are shown in ppm (Parts-per-million) - is the ratio of one gas or other molecule to another. For example, 1,000 ppm of CO_2 means that there are 1,000 molecules of CO_2 and 999,000 molecules of other gases or water vapor. In other words, 1 ppm = 0.0001% gas.

CO_2 [ppm]	Air Quality
2100 2000 1900 1800 1700 1600	BAD Heavily contaminated indoor air Ventilation required
1500 1400 1300 1200 1100	MEDIOCRE Contaminated indoor air Ventilation recommended
1000 900	FAIR
800 700	GOOD
600 500 400	EXCELLENT

Fig. 7. Indoor CO_2 Levels [4]

Elevated indoor levels of CO_2 have unfavourable effects on health. Because of poor ventilation many schools, offices, meeting rooms and bedrooms have relatively high levels of CO_2, that can influence cognitive abilities. Indoor air quality also has an impact on sleeping. Unventilated bedrooms often have high concentrations of carbon dioxide.

As a direction for further research will be to raise this sensor node to the IoT level with the possibility of automated management of ventilation systems.

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