Indoor air quality monitoring universal device

M Panaitescu 1, M V Dumitrescu 2 and F V Panaitescu 1

1 Constanta Maritime University, Faculty of Electromechanics, Engineering Sciences in Mechanics and Environment, 104 Micea cel Batran Street, PC 900663, Constanta, Romania
2 POLITEHNICA University, Doctoral School of Energy, 313 Splaiul Independentei, Sector 6, ZC 060042, Bucuresti, Romania

E-mail: panaitescumariana1@gmail.com

Abstract. This paper presents a solution for indoor air quality monitoring universal device. Existing devices on the market analyze a small number of indoor air quality parameters, require expensive consumables and periodic maintenance services. Our solution has a small volume, portable, easy to use, low price, almost non-existent maintenance, possibility monitoring a wide range of compounds and harmful elements of air. The proposed device can be equipped with a wide variety of sensors: gas sensor, digital gas sensor for air quality breakout, combined temperature and barometric pressure sensor, a 3 sensor device suitable for gas leak detection air quality monitoring. The results obtained with this device are: the individual values for each monitored element, local and online visualization of the data, the alarms for exceeding values, online access to data for analysis and processing. Finally, the solution proposed by us is cheap, we can work continuously, with the mention that if defects occur they can be remedied quickly by replacing the parts with replacement ones, without requiring periods of interruptions in the monitoring process.

1. Introduction

Recent studies indicate that certain atmospheric pollutants may exist in higher concentrations indoors than outdoors. In the past, significantly less attention was paid to indoor air pollution, compared to outdoor air pollution, especially that produced by industrial and transport emissions. In recent years, however, the threats posed by exposure to indoor air pollution have become more visible.

Poor indoor air quality can be particularly harmful to vulnerable groups, such as children, the elderly, and those with cardiovascular and chronic diseases, such as asthma.

Current devices that monitoring indoor air quality (IAQ) do this by following a minimum number of parameters, usually limited to the spaces for which they were designed. This equipment are bulky, need to be permanently monitored by specialized personnel, require consumables and specialized periodic maintenance and a purchase price of basic equipment and high consumables. Thus, we propose a more reliable structure: this has a small volume, portable, easy to use, low price, almost non-existent maintenance, possibility monitoring a wide range of compounds and harmful elements in the indoor air. Our proposed device (IAQMUD) can be equipped with a wide variety of sensors: gas sensor, digital gas sensor for air quality breakout, combined temperature and barometric pressure sensor, a 3 sensor device suitable for gas leak detection air quality monitoring.

In order to have an overview of the technical level of the equipment, we have included for comparison the following devices offered by well-known manufacturers (table 1) [1-3]:

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Table 1. An overview of the technical level of different devices.

| Type of device | Parameters |
|----------------|------------|
|                | Temp | Humidity | VOC | PM1 | PM2.5 | PM10 | CO2 | CO | N02 | H2 | NH3 | CH4 | C3H8 | Ethernet | Price (euro) |
| Testo 400      | Temp | Humidity | -   | -   | -     | -    | CO  | -  | -  | -   | -  | -   | -    | -     | Ethernet   | 1900         |
| Fluke 975      | -    | -        | -   | -   | -     | -    | -   | -  | -  | -   | -  | -   | -    | -     | Ethernet   | 2160         |
| Fluke 985      | Temp | Humidity | -   | -   | -     | -    | CO  | -  | -  | -   | -  | -   | -    | -     | Ethernet   | 4869         |
| Teledyne 602 Beta | - | - | PM1 | PM2.5 | PM10 | - | - | - | - | - | - | - | - | Ethernet | 55000        |
| Our device-IAQMUD | Temp | Humidity | VOC | PM1 | PM2.5 | PM10 | CO2 | CO | N02 | H2 | NH3 | CH4 | C3H8 | Ethernet | 1000         |

2. Research and methodology

2.1. Materials and methodology

The purpose of the work is to present the structure of a universal device for monitoring air quality. The design and manufacture of this device aims to create a versatile, adaptable, easy-to-use and maintained equipment that can be used in different indoor spaces for collecting data on indoor air quality. This device can be equipped with a wide variety of sensors. Depending on the elements that are wanted to be monitored and that present a possible danger. It is of real use in all areas where close monitoring of indoor air quality is desired: offices, classrooms, industrial spaces, homes, etc. It can be set to issue alarms for one or more monitored items. The information can be viewed online on both mobile and landline devices. Also the information collected can be stored on the PC in xls format, being available for further analysis.

The construction of the equipment was carried out around an ESP32 microprocessor [4]. It is part of a series of low power consumption microcontrollers, with integrated Wi-Fi and dual-mode Bluetooth. The ESP32 Series uses a microprocessor (Tensilica Xtensa LX6) in both dual-core and monopolar variations and includes built-in antenna switches, RF balloon, power amplifier, low noise reception amplifier, filters and power management modules. The facilities of this microcontroller allowed us to attach on most of its I2C bus most of the sensors [4]. Sensors that were not I2C compatible were connected to the digital or analogical inputs depending on the specifications of each sensor.

The internal memory of the 4MB microcontroller as well as its internet connectivity facilities, allowed the creation of an HTML page and its loading into the processor memory. We have conceived the circuit diagram of the prototype device with the EAGLE software. The prototype was built in the laboratory, following that the final, perfected version, to be made in a specialized factory.

The sensors used to make the prototype for data acquisition are:

1) gas sensor (which uses low power sensing technology to detect volatile organic compounds (VOCs) in the room and has an onboard processing capability, without host intervention, can provide the equivalent level of carbon dioxide or total volatile organic compound);

2) digital gas sensor for air quality breakout (senses a wide range of Total Volatile Organic Compounds (TVOCs), including equivalent carbon dioxide (eCO2) and metal oxide (MOX) levels); this breakout is intended for indoor air quality monitoring in personal devices such as watches and phones, but we’ve put it on a breakout board so you can use it as a regular I2C device.
The onboard of gas sensor supports multiple measurement modes that have been optimized for low-power consumption during an active sensor measurement and idle mode extending battery life in portable applications.

This sensor has the following advantages:
- Total Volatile Organic Compound (TVOC) sensing from 0 to 1,187 parts per billion;
- eCO₂ sensing from 400 to 8,192 parts per million;
- Five operating modes
- Integrated multipoint control unit (MCU);
- Onboard processing;
- Standard I₂C digital interface;
- Optimized low-power modes.

3) a sensor which operates over a wide supply range, has very low power and low cost. This sensor has the following advantages:
- Relative humidity accuracy (±2%);
- Temperature accuracy (±0.2°C);
- Excellent stability at high humidity;
- measurement resolution-14 Bit;
- Sleep mode current-100 nA.

4) combined temperature and barometric pressure sensor mounted with all components necessary to connect to a micro-controller via a simple I₂C or SPI (serial peripheral interface). This sensor can be used with an altimeter because pressure changes with altitude (±1 meter accuracy) and the advantages are (figure 1) [5]:

![Figure 1. Combined temperature and barometric pressure sensor.](image)

- Operating voltage : 1.8V – 3.6V (DC);
- Working current : 1.1mA;
- Sleep current: 0.003mA;
- Interface : I₂C or SPI;
- Temperature sensor range : (-40-80)°C;
- Accuracy : 1.0 °C;
- Resolution : 0.01°C;
- Barometric Pressure Sensor Range : 30,000-110,000 Pa
- Accuracy : 12 Pa
- Resolution : 0.18 Pa.
5) A 3 sensor device suitable for gas leak detection and air quality monitoring, which can detect many unhealthful gases; three gases can be measured simultaneously due to its multi-channels and can help to monitoring the concentration of gases where we expect the existence of more than one gas. The device can detect the following gases:

- Carbon monoxide \(\text{CO}\) (1 – 1000 ppm);
- Nitrogen dioxide \(\text{NO}_2\) (0.05 – 10 ppm);
- Ethanol \(\text{C}_2\text{H}_5\text{OH}\) (10 – 500 ppm);
- Hydrogen \(\text{H}_2\) (1 – 1000 ppm);
- Ammonia \(\text{NH}_3\) (1 – 500 ppm);
- Methane \(\text{CH}_4\) (more than 1000 ppm);
- Propane \(\text{C}_3\text{H}_8\) (more than 1000 ppm);
- Iso-butane \(\text{C}_4\text{H}_{10}\) (more than 1000 ppm).

2.2. Experimental data

The readings were taken in a mechatronics laboratory, in which different machines were operating (3D printers, desktop PC, CNC machines, etc) over a period of several days. The data are acquired using the Teraterm program (figure 2) and stored in \textsf{xls} format (table 1) [6].

The values obtained during the experiment are the local individual values for each monitored air parameter: temperature, humidity, pressure, altitude, CO, \(\text{CO}_2\), \(\text{NH}_3\), \(\text{NO}_2\), VOC, PM1, PM2.5, PM10 (e.g. live data for equipment from PC file are: temperature - 27.83\(^\circ\) C, humidity - 27.58 %, pressure -10\(^2\) Pa, altitude - 387.03 m, CO - 4.39 ppm, \(\text{CO}_2\) – 520 ppm, \(\text{NH}_3\) – 0.68 ppm, \(\text{NO}_2\) – 0.14 ppm, VOC – 18 ppm). There is also the possibility of viewing online data, triggering alarms when exceeding values. The online access of the obtained data offers the possibility of processing them and a subsequent analysis [7].
2.3. Results and graphical interpretations

The sampling rate was set for one reading per minute. The device detects variations of some of the parameters, when others remain constant (table 2).

Table 2. The variations of parameters.

| Time         | Temperature (°C) | Humidity (%) | p (10^4 Pa) | Altitudine (m) | CO₂ (ppm) | NO₂ (ppm) |
|--------------|------------------|--------------|-------------|----------------|-----------|-----------|
| 4:49:07.058  | 27.47            | 30.27        | 724.46      | 402.17         | 0.0       | 0.14      |
| 4:49:09.047  | 27.5             | 30.27        | 724.42      | 402.62         | 0.0       | 0.14      |
| 4:49:12.038  | 27.51            | 30.27        | 724.38      | 403.07         | 400       | 0.14      |
| 4:49:13.037  | 27.47            | 30.27        | 724.37      | 403.07         | 400       | 0.14      |
| 4:49:14.028  | 27.53            | 30.26        | 724.36      | 403.3          | 400       | 0.14      |
| 4:49:15.028  | 27.55            | 30.26        | 724.36      | 403.3          | 400       | 0.14      |
| 4:49:16.030  | 27.53            | 30.27        | 724.38      | 403.07         | 400       | 0.14      |
| 4:50:03.818  | 28.38            | 29.23        | 724.22      | 404.88         | 411       | 0.14      |
| 4:50:22.740  | 28.47            | 29.03        | 724.18      | 405.34         | 411       | 0.14      |

These values are read simultaneously for all the parameters, synchronized depending on time. The data can also be viewed from other online platforms (on PC and mobile phones). For each moment of the monitoring, the variation of all parameters can be graphically visualized (figure 3, figure 4).

During the 4 hours of monitoring we could find that, at the same time, some parameters remain constant (NO₂ = 0.14 ppm), while others vary (CO₂ = 0...411 ppm ).
3. Conclusions
After checking the sensor readings (calibration with certified equipment) we can say that the device successfully fulfills the main objectives.

The values indicated by the sensors mounted on the device are in the fields specified by their manufacturer. The device has a motherboard that allows the installation of a variable number of sensors, depending on the analysis requirements of the air quality parameters for the study location. The data can be accessed both locally and online. Our device can detect much more gases than other similar devices on the market.

The solution proposed by us is cheap, we can work continuously, with the mention that if defects occur they can be remedied quickly by replacing the parts with replacement ones, without requiring periods of interruptions in the monitoring process.

The solution proposed by this study allows future research directions, such as:
- adapting as many sensors as possible to the basic structure of the device;
- creating as many devices in different locations and monitoring them online;
- data acquisition from the created devices;
- creating databases.

The data obtained with this indoor air quality monitoring device can be used in other research projects.

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