Air Quality Measurement in Buildings

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Abstract: *Air quality measurement is an essential component of quality of life, since the proper functioning of ventilation (air exchange) (e.g. in passive houses) has a fundamental influence on the indoor air composition. It is very important to be able to take measurements quickly and cost-effectively. Where appropriate, it may be useful to have such a facility available to building services engineers. The sensors presented here can be used to design and build an easy-to-use measuring device.*

Keywords: *Air quality, air quality measurement, air quality sensors*

1. Introduction

Indoor air quality is important for quality of life and health [1]. Its perception is therefore very important in the field of engineering.
Key features that are important for us:

- indoor temperature,
- indoor pressure,
- humidity,
- carbon dioxide concentration,
- volatile organic compounds (VOC-s).

To a large extent, our sense of thermal comfort depends on:

- air temperature (this is usually controlled),
- relative humidity (which indicates the water vapour content in the air and should be between 40-60%),
- air composition (of which the percentage of oxygen and carbon dioxide is of greatest biophysical importance).

The concentration of these two gases changes very rapidly in indoor spaces. A change in the CO_2 content of the air we breathe has a greater effect on the human body than a comparable change in the oxygen content. **Consequently, monitoring carbon dioxide level is an essential element of air composition monitoring.**
To maintain good air quality and reduce CO_2 concentration, the building should be ventilated continuously. **However, ventilation is an energy intensive process**.
At the same time, the increased CO_2 content in the air we breathe causes adverse reactions in the human body:

- reduces attention and
- causes drowsiness.
- When the concentration of carbon dioxide reaches a fraction comparable to that of oxygen (around 20%), it might even be life-threatening.
- If the CO_2 content in the air ones breathe rises above 1000 parts per million (ppm), one will not only feel drowsy and lose concentration, but also feel short of breath and have a rapid heartbeat.

2. Legislation on indoor CO_2 concentrations

Developed countries in North America and Europe place great emphasis on air quality standards and indoor CO_2 content [2].
Mandatory standards for ventilation [3, 4, 5, 6]:

- United States of America
  - ASHRAE 62.1-2013 [3]

- Europe
  - EN-15241:2011 [4],
  - EN-15242:2009 [5] and
  - EN-13779:2008 [6].

They aim to achieve good indoor air quality.
The figure below shows how different concentrations of carbon dioxide in the air we breathe affect the human body [7].

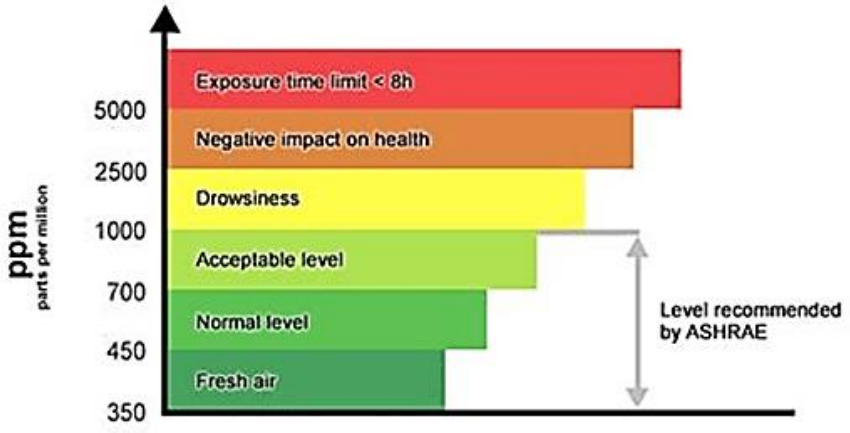

Fig. 1. Characterisation of CO_2 concentration and its effects on the human body [7]

3. Air quality sensors

Typical applications of air quality sensors:

- Indoor air quality detection,
- Home automation and control,
- Weather forecast.

3.1. BME 680 Bosch air quality sensor [8]

The BME 680 is a digital 4-in-1 sensor that measures

- gas,
- humidity,
- pressure and
- temperature.

Fig. 2. BME 680 Bosch air quality sensor [9]

3.2. Main operating characteristics of the sensor

- Operating range -40 - +85°C, 0-100% relative humidity, 300-1100 hPa
- Key parameters of the gas detector
  - Response time (τ 33-63%) <1 s (for new sensors)
  - Power consumption <0.1 mA in ultra-low power mode
  - Output data processing direct indoor air quality (IAQ) index output

- Key parameters of the humidity sensor
  - Response time (τ 0-63%) ~ 8 s
  - Accuracy tolerance ± 3% r.H.
  - Hysteresis ± 1.5% r.H.
- Key parameters of the pressure sensor
  - RMS noise 0.12 Pa, eq. up to 1.7 cm
  - Temperature coefficient ± 1.3 Pa/K, eq. ± 10.9 cm for temperature changes up to 1 °CI used FMSv4.5 software for evaluating the results of the measurement.

3.3. Using the sensor

The sensor supports low-power modes:
- sleeping and
- forced mode.

These modes can be selected using the mode control register.
After the switch-on process, the sensor automatically starts in the sleep mode. If the device is currently measuring, the execution of the mode change commands is delayed until the end of the currently running measurement period.

3.3.1. Temperature measurement

Temperature measurement can be enabled or disabled.
- If the IIR filter is enabled, the temperature resolution is 20 bits.
- If the IIR filter is disabled, the temperature resolution is 16 bits.

3.3.2. Pressure measurement

Pressure measurement can be enabled or disabled. If enabled, there are several sampling options. The resolution of the pressure data depends on the IIR filter and the oversampling settings:
- If the IIR filter is enabled, the pressure resolution is 20 bits.
- If the IIR filter is disabled, the pressure resolution is 16 bits.

3.3.3. Humidity measurement

Humidity measurement can be enabled or disabled. If enabled, there are several sampling options. The resolution of the humidity measurement is recorded on a 16-bit ADC output.

3.3.4. Read data

After reading the uncompensated values of temperature, pressure and humidity, the actual humidity, pressure, and temperature shall be calculated using the compensation parameters stored in the instrument.

3.3.5. BSEC software

The BSEC software includes intelligent algorithms that allow use cases such as indoor air quality monitoring using the BME680.
The Bosch Sensortec BSEC software is available in closed source binary form, made available through a Software License Agreement (SLA) on the Bosch Sensortec website.
The main features of the hardware-software system are:
- Calculate the ambient air temperature outside the device (e.g. telephone)
- Calculating the ambient relative humidity outside the device
- Calculating indoor air quality (IAQ) outside the appliance.

3.3.6. How the BME 680 sensor works

The BME 680 is a metal oxide-based sensor that detects VOCs by adsorption (and subsequent oxidation/reduction) on its sensitive layer.
Thus, the BME680 reacts to most volatile compounds that pollute indoor air (except for CO_2). BME680 can measure the amount of VOCs/pollutants in the ambient air. This allows the BME680 to detect e.g. fumigation from paint, furniture and/or garbage, high VOC levels due to cooking, food consumption, exhaled breath and/or perspiration.

The raw values are converted into Indoor Air Quality (IAQ) indices by intelligent algorithms within BSEC.
The IAQ scale ranges from 0 (clean air) to 500 (highly polluted air). During operation, the algorithms automatically calibrate and adapt to the typical environment in which the sensor operates (e.g. home, workplace, inside a car, etc.).
This automatic background calibration ensures that users experience consistent IAQ performance. **The calibration process takes into account the most recent measurement history (typically up to four days) to ensure that IAQ ~ 25 corresponds to "typical good" air and IAQ ~ 250 indicates "typical polluted" air.**

4. SEN-16531 - SGP30 Qwiic air quality sensor

The SparkFun SGP30 Air Quality Sensor [10] provides information about the air quality in a room or house by detecting volatile organic compounds around the sensor. The SGP30 air quality sensor can provide valid Indoor Air Quality (IAQ) values within 15 seconds of power-up.

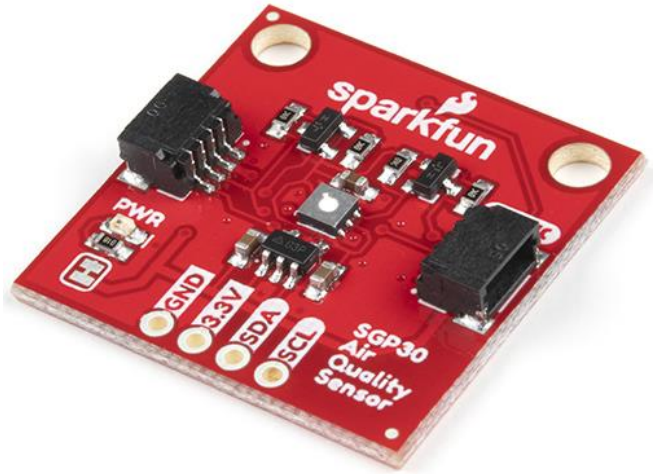

Fig. 3. SEN-16531 - SGP30 Qwiic air quality sensor [10]

Most air quality (IAQ) sensors require a start-up time of around 20 minutes. 15 seconds is considered an excellent value.
In addition to a very fast start-up time, the sensor is resistant to contamination by other gases, providing long-term stability and highly reliable results.
Output values of the SGP30 gas detector:

- VOC (TVOC),
- carbon dioxide (CO_2),
- H_2,
- ethanol.

The SparkFun Qwiic Connect System (sensor interface and system) is a system of I2C sensors, actuators, shields and cables that facilitates prototyping.
All Qwiic-compatible cards share a common 1 mm pitch and use a 4-pin JST connector. This reduces the size of the required PCB (printed circuit board) area, and the polarised connections ensure freedom from misconnectivity.
The SGP30 air quality sensor is automatically detected, scanned, configured, and logged by the Open Log Artemis data collection system.
Key features of the SEN-16531 - SGP30 Qwiic air quality sensor

- Operating voltage:
  - 1.62V - 1.98V (Typ. 1.8V)
  - When using Qwiic cable, regulated voltage: 1.8V - 3.3V
- TVOC signal:
  - Output band: 0 ppb - 60,000 ppb
  - Resolution: 13 ppb.

- CO_2 signal
  - Output band: 400 ppm - 60,000 ppm
  - Resolution: 11ppm
- Ethanol signal:
  - Measuring range: 0 ppm to 1,000 ppm
  - Resolution: 0.2% of the measured value
- H_2 signal
  - Measuring range: 0 ppm to 1,000 ppm
  - Resolution: 0.2% of the measured value
- Typical current consumption (depending on operating mode)
  - 48.2 mA (measuring mode)
  - 2µA - 10µA (sleep mode)

5. Summary

The ability to carry out a documentable energy assessment of the boundary surfaces of heated/cooled spaces as accurately and reproducibly as possible and within a shorter time is very important.
However, all this is complemented by the physical and chemical quality of the indoor air. The need therefore arises to increase the complexity of the measurement tool.
The values to be measured are VOC, CO_2, H_2, ethanol concentration, together with air humidity, pressure, and temperature.
Selected sensors:

- BME 680 Bosch air quality sensor and
- SEN-16531 - SGP30 Qwiic air quality sensor.

My goal is to create an affordable, marketable prototype tool that is labour-saving, efficient to use and cost-effective. This objective and documentable tool is expected to be most beneficial or of use for construction/civil engineering companies.
It will be suitable for a complex assessment, analysing energy aspects in synergy with indoor air quality measurements.
The benefits that come with using it:

- A cheap, easy-to-use solution for a preliminary survey
- Based on the results, the renovation technology and the exact selection of the required insulation materials, windows and ventilation systems can be planned.

Acknowledgement

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