Air Quality Detection and Display;

Revised Project Proposal

Alexia Morales-Rodriguez, Vivian Tran

Faculty of Engineering, University of Waterloo

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Professor David Lau

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Needs Assessment

Customer Definition

Air pollution continues to be a serious concern worldwide, moving past tobacco and poor diet to become the second leading cause of death in the world [1]. In Canada, air pollution is associated with over 15,000 [2] premature deaths per year. Without keeping track of the air quality, individuals unknowingly expose themselves to high concentrations of pollutants, increasing the risk of various health problems, potentially leading to death. As well, this is a serious issue for those who have existing pulmonary illnesses, specifically Chronic Obstructive Pulmonary Disease (COPD).

According to the Global Initiative for Chronic Obstructive Pulmonary Disease [3], COPD is defined as “a heterogeneous lung condition characterized by chronic respiratory symptoms (dyspnea, cough, sputum production and/or exacerbations) due to abnormalities of the airways (bronchitis, bronchiolitis) and/or alveoli (emphysema) that cause persistent, often progressive, airflow obstruction”. In Canada, COPD affects 10% of the population ages 35 and older [4] and is the second leading cause of hospitalizations [5].

In the presence of low air quality, individuals with COPD may experience worsened symptoms, such as inflammation of lung tissue cells [6], leading to decreased lung function, as well as increased morbidity and mortality rates [7]. In 2016, ambient air pollution accounted for 43% of COPD deaths [8]. Historically, the Region of Waterloo has experienced higher levels of risk in regards to air quality throughout 2024 [9], thus this design targets this region. In specific, this design addresses individuals ages 35 and older with COPD within the Region of Waterloo. COPD affects 4.7% of the population [10], which amounts to approximately 34 000 people.

Competitive Landscape

The world has long been aware of the effects of poor air quality on one's health. Thus, multiple solutions to address the challenges that the client is facing have been implemented in the past with varying effectiveness.

Online Air Quality Map

The Government of Canada provides an online local air quality index for several Canadian cities across the country [11]. It uses the Canadian Air Quality Health Index (AQHI) and includes a legend for those who are unfamiliar with the scale. This resource, however, is overly reliant on the internet, as it is an online source and reports the air quality for large areas, which reduces accuracy. In terms of Waterloo, the page only addresses Kitchener with one AQHI. This generalizes the area and does not account for any deviations in air quality within the area.

Climate Change Initiatives

The worsening of air quality in Canada and around the world is due to climate change, which is caused by human activities that involve the emission of greenhouse gases, such as the burning of fossil fuels [12]. In order to combat this, governments can pass policies and laws, such as a carbon tax in an effort to dissuade the use of climate-unfriendly practices. Unfortunately, this process is usually slow to instill due to the several stages a bill has to go through to become a law [13]. As well, a major, positive change in climate would take a minimum of several years [14]. It would be impractical and disruptful for an individual with COPD to wait until the climate improves in order to go outside.

Self-Checking

One may be able to monitor the air quality outdoors using their own senses, mainly smell [15]. Depending if the smell is unpleasant, the individual can choose to stay indoors. However, this process is largely unreliable due to subjectivity of olfaction. As well, the method requires the individual to deliberately breathe in the outdoor air to test its quality, which undermines the purpose of staying indoors to protect one from inhaling pollutants that are present outside, possibly worsening the individual's health in the process [16].

Requirement Specification

Functional Requirements

The following requirements define the operations of the system that the client will expect and the specifications they want to be aware of:

Air Quality Detection

The gas sensors of the device will detect harmful pollutants such as ozone (O_3), nitrogen dioxide (NO_2), and fine particulate matter (PM2.5) with a concentration ranging from 10–10 000 ppm, as this is the standard for most gas sensors compatible with the STM32F401RE microcontroller being used [17].

Data Display

To indicate health risk levels, the system will employ LEDs emitting wavelengths from 520–633 nm, corresponding to red, yellow, green and blue, which indicate very high risk to low risk, respectively. These colors were chosen as “our eyes catch the light emitted by red, blue, and yellow the fastest” and “green is associated with calmness” [18].

With an approximate generating time of 5–15 seconds for each gas sensor, the data will be processed and displayed every 30 seconds as “It is always wise to obtain multiple measurements over the widest range possible” [19], ensuring data is more consistent (Sample Mean Principle).

Technical Requirements

The following requirements specify the technical operations within the system that the engineers are concerned with, so that the product may function as intended:

Air Quality Detection

The system will display air quality levels according to health risk. To determine at which level the air quality is at, gas concentrations will be calculated. Depending on the gas, the range may vary but the base scale will be,

- Low risk: 10–3500 ppm
- Moderate risk: 3501–6500 ppm
- High risk: 6501–8 500 ppm
- Very high risk: 8501+ ppm

These ranges were chosen according to the minimum and maximum concentration each sensor can detect and their association with low density and high density gas inputs [17].

Power Supply

The sensor system will operate with a supply voltage between 3.3V–5V DC in order to account for both the amount of volts the microcontrollers need to operate, as well as the sensors, without burning out the LEDs [20].

Resistors

The LEDs must remain on and continuously display light without burning out, thus, 20–100 ohm resistors will be placed along the system to account for each diode's max input [21]. This will help "control the amount of current flowing through the circuit", protecting the sensitive components from damage and allowing for optimal visual communication [22].

Safety Requirements

The following requirements ensure that the engineers and client remain safe during the construction and implementation phases:

Thermal Safety

The system will operate within the specified temperature range of the gas sensors and the STM32F401RE microcontroller to remain within safe temperature limits, avoiding overheating that could result in component failure or fire risks [23].

Electrical Safety

The system will include current-limiting resistors for LEDs and sensors to avoid excessive current draw and potential damage to both the engineer and component [14].

Environment Safety

The gas sensors will be calibrated according to the manufacturer's specifications to avoid inaccurate readings and ensure reliable air quality measurements.

Analysis

Design

The solution to the problem consists of an air quality monitor that takes measurements of particles in the air and displays a corresponding level of risk through LEDs, as well as the concentrations of each particle measured on the LCD.

Components

The solution consists of the following main components:

- STM32 Nucleo-64 development board (2)
- 16x2 LCD module (1)
- Blue LEDs (2)
- Green LEDs (2)
- Yellow LEDs (2)
- Red LEDs (2)
- MQ131 Ozone Sensor (1)
- PMS5003 Particulate Matter Sensor (1)
- SEN0574 MEMS Nitrogen Dioxide NO_2 Gas Detection Sensor (1)

Modules

The design is split into two modules: the Sensor Module and the Display Module.

Sensor Module

The Sensor Module consists of one STM32 Nucleo-64 development board, and all sensors. Its purpose is to collect the concentrations of air particles in order to send this information to the Display Module.

Display Module

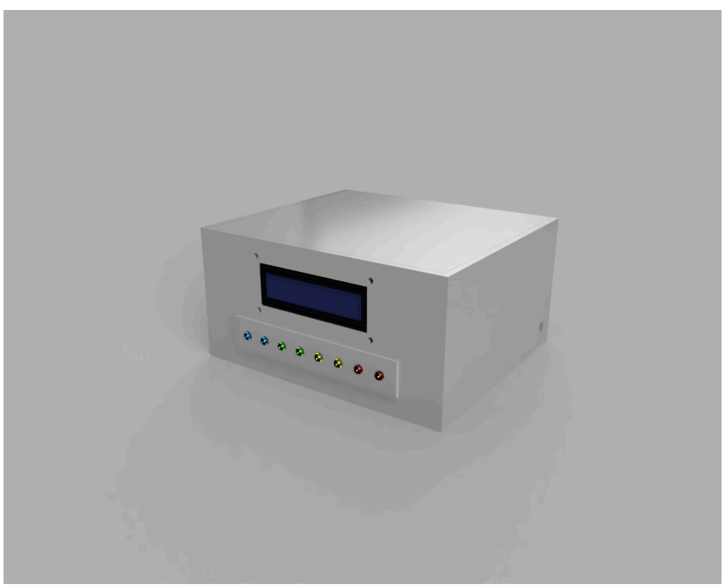
The Display Module consists of one STM32F401RE Nucleo board, the LCD module, and all LEDs. Its purpose is to receive data from the Sensor Module and display relevant data to the user about the air quality in the surrounding area in which the Sensor Module is placed. The LEDs displayed correspond to the normalization of the Canadian Air Quality Health Index (AQHI).

Using the Design

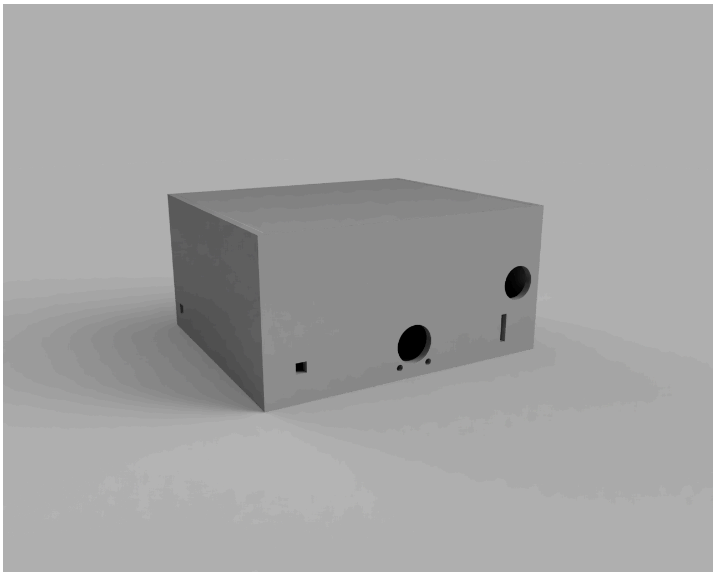
The goal of this design is to clearly convey the quality of air around the user's area. After powering the design on, the design will begin monitoring the air. The readings are updated every 30 seconds. To check the air quality, the user will observe the colour of the LEDs. Each colour of the LED corresponds to a certain risk level as denoted by the Canadian AQHI, with blue corresponding to Low Risk and red corresponding to Very High Risk.

Rendered Design

Display Module

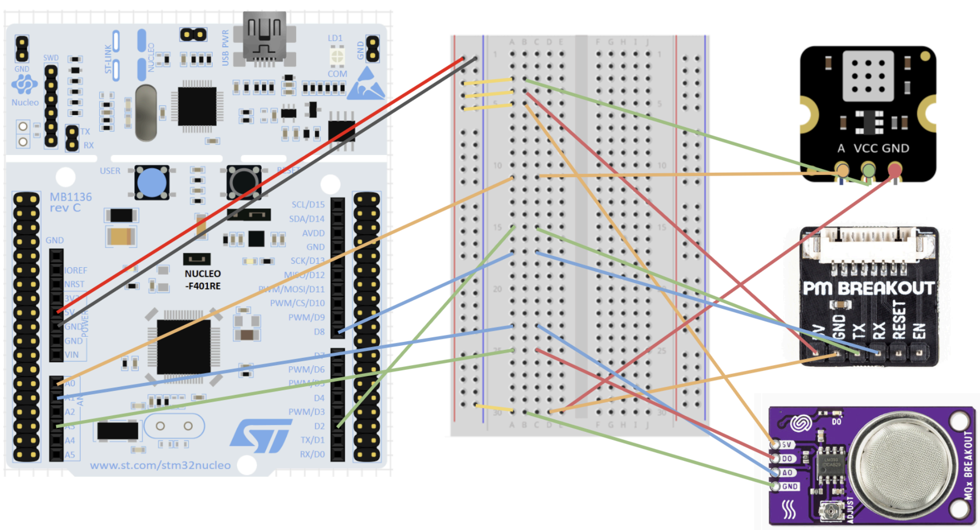


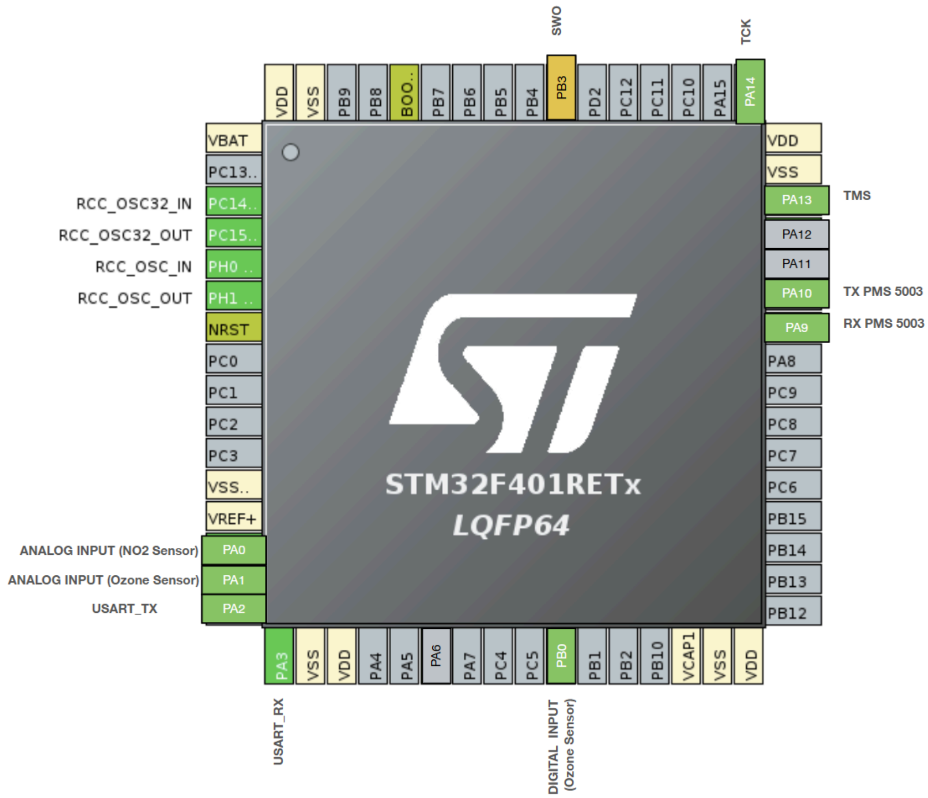
Sensor Module (Missing Sensors)



Circuit Drawing

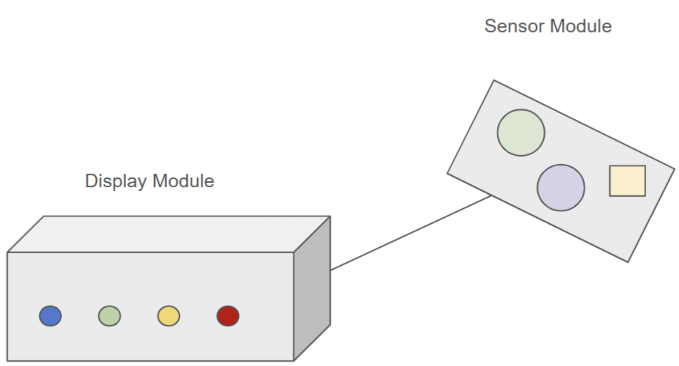
Sensor Module:



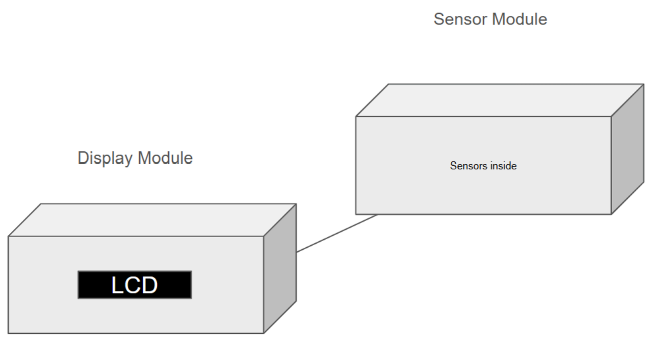


Design Alternatives

Alternative 1



Alternative 2



Ultimately, these two alternatives were not selected due to their respective shortcomings. The first option utilized LEDs in the display module and positioned the gas sensors on a flat surface, allowing for easier exposure to environmental conditions. However, despite this slight advantage, it presented several significant drawbacks. The exposed gas sensors were vulnerable to weather damage, breakage, and other potential hazards, raising concerns about data reliability and the effectiveness of the sample mean theorem.

The second alternative provided coverage for the gas sensors, eliminating the risk of inconsistency, and used an LCD as the display component. Though, research indicates colours and lights tend to be more easily processed by the human brain [18].

As a result, the final design was chosen as it combines the strengths of both alternatives, creating the most reliable, readable, and durable air quality detector.

Scientific and Mathematical Principles

Calculation of particle concentration using a sample mean

Individual measurements of particle concentrations in the air can vary greatly, and can possibly include outliers. To prevent the design from constantly updating the apparent quality of the air, which may be confusing to users, a sample mean is used to estimate the average concentration over an interval of time:

$$mean\ concentration = \frac{1}{n}\sum_{i=1}^{n} x_i$$

n: the total amount of samples taken

x: sample concentration

Determining appropriate resistance for LEDs: Ohm's Law

LEDs are an integral part of the design's communication functions to the customer. Ensuring the LED is not only reasonably bright, but does not pose an inconvenience or danger to the customer by burning out is essential.

$$appropriate\ LED\ resistance = \frac{V_{supply} - V_{forward}}{I_{forward}}$$

V_{supply}: supply voltage; 3.3 V

$V_{forward}$: LED voltage drop; varies between LED colours, measured individually

Example: Calculating the resistor value for a blue LED

$$appropriate\ LED\ resistance = \frac{5.0\ V - 3.0\ V}{20\ mA} = 100\ \Omega$$

Therefore, the current limiting resistor for one of the blue LEDs in the design should be 100 ohms.

Placing Resistors: Resistors in Series or in Parallel

In order to reflect the calculated resistance for a component, one must use the equations for resistors in series or parallel to arrange the resistors correctly. Given the large amount of LEDs in use, it is imperative to ensure all LEDs have a consistent brightness and do not burn out. As well, in an ideal situation, any failure in a LED should not cause the rest of the LEDs to fail. This is only possible with parallel circuits, which resistance needs to be determined for.

Resistance in Series: $R = \sum_{i=1}^{n} R_i$

Resistance in Parallel: $\frac{1}{R} = \sum_{i=1}^{n} \frac{1}{R_i}$

Calculating the Air Quality Health Index: Floating Point Arithmetic

The Air Quality Health Index used by Canada is computed using the following equation [25]:

$$AQHI = \frac{10}{10.4} \times 100 \times [(e^{0.000537 \times O_3} - 1) + (e^{0.000871 \times NO_2} - 1) + (e^{0.000537 \times PM_{2.5}} - 1)]$$

Within a program, floating point arithmetic must be applied in order to compute this value. Computers today use the technical standard, IEEE 754 [26] to represent floating point numbers, which will be used to calculate the index, as the formula involves the use of real numbers, represented as floating point numbers in code, to compute the AQHI. The AQHI is a fundamental index in the air quality monitor as it determines the risk level of the current air quality, displaying the calculated value through the LEDs and the LCD.

Mapping the calculated Air Quality Health Index to eight LEDs: Quantization

Canada's Air Quality Health Index (AQHI) is a discrete scale from 1 to more than 10. These values will have to be mapped onto a discrete amount of LEDs in order to properly communicate the air quality to the customer.

$LED_n = [\frac{(index-10)-1}{10-1} \cdot (8 - 1)] + 1$

Square brackets indicate rounding

index: AQHI value

1 indicates up to the first LED, 8 indicates up to the last LED from left to right

Manufacturing and Implementation Costs

Bill of Materials

Microcontroller

STM32 Nucleo-64 development board

- Price: $19.92 CAD
- Quantity: 2
- Manufacturer: STMicroelectronics, Chemin du Champ-des-Filles 39, 1228 Plan-les-Ouates, Switzerland
- Distributor: DigiKey Corporation, 701 Brooks Avenue South, Thief River Falls, MN 56701, United States

Sensors

MQ131 Ozone Sensor Breakout

- Price: $25.91 CAD
- Quantity: 1
- Manufacturer: No. 299 Jinsuo Road, High-tech Development Zone, Zhengzhou, Zhongyuan District, Henan, China
- Distributor: DigiKey Corporation, 701 Brooks Avenue South, Thief River Falls, MN 56701, United States
- Vendor: Soldered Electronics Ltd., Reisnerova ulica 100, 31000 Osijek, Croatia

PMS5003 Particulate Matter Sensor and Cable

- Price: $37.95 CAD
- Quantity: 1
- Sensor Manufacturer: Nanchang Panteng Technology Co., Ltd. (Plantower Technology), Building 9, Yuxi Road No. 9, Houshayu, Shunyi District, Beijing, China

- Cable Manufacturer: Pimoroni Ltd., Unit 1, Parkway One, Business Park, Parkway Dr, Darnall, Sheffield S9 4WN, United Kingdom
- Distributor: Pimoroni Ltd., Unit 1, Parkway One, Business Park, Parkway Dr, Darnall, Sheffield S9 4WN, United Kingdom
- Vendor: PiShop.ca, 9-190 Colonnade Rd., Ottawa ON, K2E 7J5

SEN0574 MEMS Nitrogen Dioxide NO_2 Gas Detection Sensor

- Price: $11.61 CAD
- Quantity: 1
- Manufacturer: DFRobot, Room 501, Building 9, No 498 Guoshoujin Road, Pudong, Shanghai, China
- Distributor: DigiKey Corporation, 701 Brooks Avenue South, Thief River Falls, MN 56701, United States

Circuit Components

Through Hole Resistor

- Price: $15.99 CAD
- Quantity: 9
- Manufacturer: Elegoo Inc., Room 101, No. 30, Dahe Industrial Zone, Guancheng Community, Guanhu Street, Longhua District, Shenzhen, Guangdong, China
- Distributor: Amazon.com, Inc., 410 Terry Ave N, Seattle, WA 98109, United States

HD44780 16x2 LCD

- Price: $13.82 CAD
- Quantity: 1
- Manufacturer and Distributor: Adafruit Industries, 168 39th St Suite 1905CC, Brooklyn, NY 11232, United States

5 mm LED

- Price: $15.99 CAD (bulk)
- Quantity: 8
- Manufacturer: Elegoo Inc., Room 101, No. 30, Dahe Industrial Zone, Guancheng Community, Guanhu Street, Longhua District, Shenzhen, Guangdong, China
- Distributor: Amazon.com, Inc., 410 Terry Ave N, Seattle, WA 98109, United States

Particulate Matter Sensor Breakout (for PMS5003)

- Price: $5.45 CAD
- Quantity: 1
- Manufacturer: Pimoroni Ltd., Unit 1, Parkway One, Business Park, Parkway Dr, Darnall, Sheffield S9 4WN, United Kingdom
- Vendor: PiShop.ca, 9-190 Colonnade Rd., Ottawa ON, K2E 7J5

10K Potentiometer

- Price: $41.99 CAD (kit)
- Quantity: 1
- Manufacturer: Elegoo Inc., Room 101, No. 30, Dahe Industrial Zone, Guancheng Community, Guanhu Street, Longhua District, Shenzhen, Guangdong, China
- Distributor: Amazon.com, Inc., 410 Terry Ave N, Seattle, WA 98109, United States

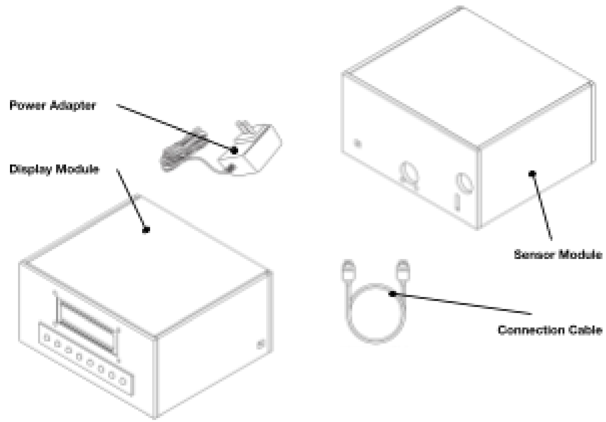
Other Costs

PLA Filament

- Price: $17.57 CAD
- Distributor: University of Waterloo Rapid Prototyping Centre, 200 University Ave W, Waterloo, ON N2L 3G1

Installation Manual

Parts Diagram



Assembly and Mounting

1. **Connect Modules Together**

   Take all parts out of packaging and connect the communication cable securely between the Display Module and the Sensor Module via the ports located on the back face of each module.

2. **Plug the Power Supply Cord**

   Plug the power supply cord attached to the Display Module securely into an outlet.

   The LCD screen located on the module will illuminate, indicating that the monitor is on. The monitor will begin monitoring the air quality immediately after power has been provided.

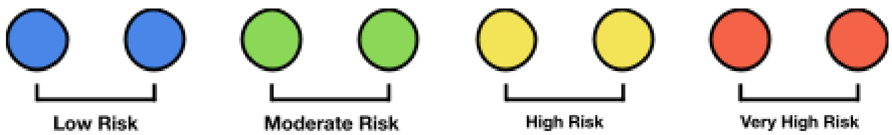
3. **Mounting**

   Place the Display Module in an interior location and the Sensor Module in an exterior location on a flat surface, ensuring rubber pads are flush to the surface.

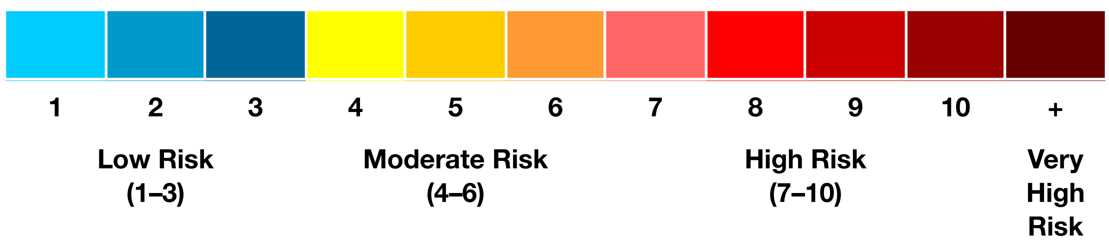
User Guide

Interpreting Risk Level

When unable to read the LCD for risk levels, the row of eight LEDs on the Display Module indicate an approximate risk level. It can be interpreted as follows, with each circle corresponding to an LED:



Canada's AQHI is provided for reference [11]:



Troubleshooting Guide

LCD and LEDs are Off

Check if the connection between the power supply is secure. If the problem persists, unplug the power supply and replug it in.

LCD Text is Too Dim

Adjust the contrast of the LCD: Slide off the lid of the Display Module. Locate the potentiometer (black knob) mounted near to the right side of the LCD. Adjust the knob until the text on the LCD is clear.

Air Quality is Not Updating Regularly

If air quality levels are not updating every 30 seconds, check if the connection between the Display Module and the Sensor Module is secure. If the problem persists, fully disconnect the connection between the modules then reconnect.

Risks

Energy Analysis

Using the IEEE USB Port and power delivery reference standard [27], this design is able to efficiently use power management to stay within the project requirements. The standard refers to the efficient use of USB power sources and the benefits they grant to the system to have low energy consumption. As this design will use an AC to DC USB power adapter this reference stands well.

Proof of Power source (≤ 30W):

Power Consumption

The project requirements give a reference that "the design must not consume, transfer, discharge, or otherwise expend more than 30W of power at any point in time and within any component of the design during its operation."

Considering there are no moving parts within the system, mechanical kinetic energy and mechanical potential energy were discarded as sources of energy. As capacitors, and other forms of external energy storage were not used in the system, electric potential energy also was not part of the energy analysis. Thus, leaving the electric energy of the system to be analysed.

What	Name	# parts	Volts	Current	Power
Microcontroller	STM32F401RE	2	5.0 V	150 mA	0.75 W
Nitrogen Dioxide Sensor	DFRobot SEN 0574	1	5.0 V	<20 mA	0.1 W
Particulate Matter Sensor	PMS5003	1	5.0 V	<=100 mA	0.5 W
Ozone Sensor	MQ131	1	5.0 V	180 mA	0.9 W
Screen	LCD	1	5.0 V	35 mA	0.175 W
Diode	Red LED	2	2.0 V	20 mA	0.04 W
Diode	Yellow LED	2	2.8 V	20 mA	0.056 W
Diode	Green LED	2	2.8 V	20 mA	0.056 W
Diode	Blue LED	2	2.8 V	20 mA	0.056 W
				TOTAL	**3.59 W**

Using the Scientific principle of power $P = VI$, it is clearly seen that throughout the system, at any point in time, each component operates at low power levels, and there will never be an expenditure of over 30W of combined power. Further proving the limits were met and the reference standard is appropriate for the design.

Energy Storage

Additionally, the project requirements give another reference standard that "the design must not store or otherwise contain more than 500mJ of energy at any point in time."

By first analysing the geometry of the circuit and its components, it's clear that not a significant amount of energy storage would occur, if any. This is because the peripherals used within the system such as gas sensors, particulate matter sensors, and LEDs do not have the capacity to store energy, and there are no capacitors used within the system. The power source of the design will also be an AC to DC

USB power adapter, so no chemical energy of a battery will be used either. Thus, based on this analysis, the total energy stored in the system is essentially none, successfully being under the 500 mJ limit.

Risk Analysis

With any system, there are possible risks that should be considered. This includes when the design is used as intended, used incorrectly, not used as intended or if the design malfunctions. Each event poses as a failure mechanism that may have negative consequences on safety or the environment; so, an analysis will be conducted such that each situation and result will be specified in preparation for the worst-case scenario.

Consequences from Intended Use

1. **Safety Hazards:**
    - Using microcontrollers and sensors can create electrical hazards if the wiring isn't properly insulated or is faulty.
        - **Consequence:** This could lead to electric shock for the client or damage to the device.

2. **Electronic Waste:**
    - Improper disposal of the electronic components after their life cycle ends could lead to environmental pollution.
        - **Consequence:** Accumulation of electronic waste could harm ecosystems if not disposed of correctly

Consequences from Incorrect Use

1. **Exposure to Extreme Conditions:**
   - Incorrectly setting up the sensors or microcontrollers can lead to inaccurate air quality readings. This may also include using the design within the wrong temperature or humidity ranges as specified in the functional requirements.
     - **Consequence:** This will most likely lead to unreliable data, exposing users to unhealthy and unsafe air.
2. **Misreading LED Indicators:**
   - If users do not properly process the LED colour indicators for air quality, they will be ignoring vital alerts.
     - **Consequence:** Ignoring poor air quality signals could lead to health risks from exposure to pollutants.

Consequences from Unintended Use

1. **Physical Damage:**
   - Dropping or mishandling the design, such as dropping it or exposing it to moisture, could damage the components.
     - **Consequence**: Make the design unusable or inaccurate, compromising safety and health of the user through poor air quality readings or exposed electrical hazards.
2. **Environmental Set-up**
   - Using the design to detect gases other than the ones specified, will not result in accurate readings.
     - **Consequence:** Users will be relying on unreliable data, possibly exposing themselves to poor air quality.

- Purposefully setting up the design in an unrealistic environment of extremely high concentrations of gases could damage sensors, and expose users to harm.
    - **Consequence:** Users will be putting themselves at risk by either receiving poor air quality readings, or by mere exposure to high gas concentrations.

Possible Malfunctions

1. **Sensor Failure:**
    - Over time, sensors may deteriorate, leading to poor detection of harmful gases, displaying unreliable data.
        - **Consequence**: Users may receive inaccurate assessments of air quality, potentially leading to health risks.
2. **Communication Issues:**
    - A failure in the wired connection between the two microcontrollers could interrupt data transfer to the second microcontroller.
        - **Consequence**: Loss of real-time air quality monitoring, which could delay necessary data information where users could be misinformed about air quality levels, leading to uninformed and unsafe decisions.
3. **Power Failure:**
    - A failure in the consistency/stability of the power source will lead to inconsistent operation of the microcontrollers.
        - **Consequence**: The design will fail and have a period of time where it doesn’t monitor air quality, risking user safety.
4. **Display Malfunction:**
    - If the LEDs fail and or the LCD does too, users will not receive accurate visual cues about air quality.

- **Consequence:** There will be a lack of proper alerts, increasing risk of health issues and exposure to poor air quality.

Testing and Validation

Test Plan

To ensure proper functioning of the design in accordance with the specified requirements, five tests were created that validate several functionalities of the design.

Given that the air quality monitor measures the concentration of toxic gases and irritants, the deliberate introduction of these particles for testing purposes would pose a danger to those nearby. Instead, any measurement of particles will be emulated with a digital or analog signal, depending on the sensor.

Correct LEDs are displayed according to the measured air quality

Setup and Environmental Parameters

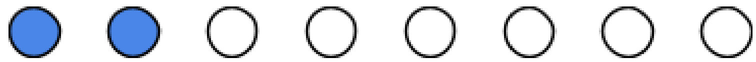
Ensure that the monitor has power. Since this test only involves display, environmental parameters are specified in order to prevent any external factors affecting the design's performance. The test should be performed in an environment with consistent humidity and temperature, similar to that of room temperature and humidity in order to prevent any component failures while testing.

Test Inputs and Measurements

Given a certain set of readings from the sensors, the LEDs on the monitor should match each diagram provided, with any circle without colour corresponding to an LED being off, and any circle with colour corresponding to an LED of that colour being on.

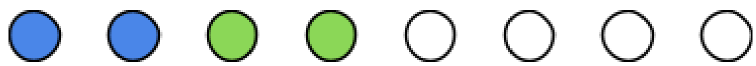
Low Risk

- Ozone: 0.015 ppm
- Nitrogen Dioxide: 0.015 ppm
- Particulate Matter < 2.5 microns: 0.015 ppm
- LED Display:



Moderate Risk

- Ozone: 0.025 ppm
- Nitrogen Dioxide: 0.025 ppm
- Particulate Matter < 2.5 microns: 0.025 ppm
- LED Display:



High Risk

- Ozone: 0.05 ppm
- Nitrogen Dioxide: 0.05 ppm
- Particulate Matter < 2.5 microns: 0.05 ppm
- LED Display:

Very High Risk

- Ozone: 0.06 ppm
- Nitrogen Dioxide: 0.06 ppm
- Particulate Matter < 2.5 microns: 0.06 ppm
- LED Display:

Pass Criteria

Each test is passed if the specified LEDs in each diagram light up in accordance with the inputted particle concentrations.

The air quality index updates regularly

Setup

Ensure that the monitor has power. Wait at least 30 seconds in order to let the monitor measure an initial concentration of particles in the air before testing. Have a spray bottle filled with tap water ready for use.

Environmental Parameters

As the test involves inducing a sharp change in the ambient particle concentration, the humidity and temperature of the room the design is being tested in should remain fairly constant. In case of a change in the environmental conditions of the room, wait until the conditions stabilize before testing.

Test Input and Measurement Standard

Position the spray bottle approximately 15 cm normal to and at the same height as the back face of the Sensor Module, positioned at the leftmost vertical edge of the back side. While holding the spray bottle's nozzle parallel to the back side of the module, spray three pumps of water. Wait 30 seconds.

Refer back to the Display Module. There should be a visible change in the level of PM2.5 displayed on the LCD every thirty seconds. Use any timer to measure intervals of time.

Pass Criteria

The test is passed if the input successfully updates the average particle concentration regularly.

The average air quality is correctly displayed on the LCD

Setup and Environmental Parameters

Ensure that the monitor has power. Since this test only involves display, environmental parameters are specified in order to prevent any external factors affecting the design's performance. The test should be performed in an environment with consistent humidity and temperature, similar to that of room temperature and humidity in order to prevent any component failures while testing.

Test Input and Measurement Standard

Given a certain concentration of pollutants, the LCD should correctly display the same concentration:

- Ozone: 0.06 ppm
- Nitrogen Dioxide: 0.06 ppm
- Particulate Matter < 2.5 microns: 0.06 ppm

Refer to the LCD and observe the outputted values.

Pass criteria

The LCD displays the same air quality measurement as the values known before the test.

The risk level displayed by the LCD matches the risk level displayed by the LEDs

Setup and Environmental Parameters

Ensure that the monitor has power. Since this test only involves display, environmental parameters are specified in order to prevent any external factors affecting the design's performance. The test should be performed in an environment with consistent humidity and temperature, similar to that of room temperature and humidity in order to prevent any component failures while testing.

Test Input and Measurement Standard

Given a set of particle concentrations, the risk level conveyed by the LEDs should match that of the LCD in order to reduce any confusion. Low Risk and Very High Risk will be tested.

Pass Criteria

The test is passed if the LCD displays the same risk level as the colour the LED corresponds to.

The average air quality index is properly calculated

Setup

Ensure that the monitor has power. That the gas sensors are operational, and communication between microcontrollers is functional.

Environmental Parameters

The test involves calculating air quality accurately, and so the conditions of the room must be controlled with constant temperature, humidity and known concentrations of gases. In case of a change in the environmental conditions of the room, wait until the conditions stabilize and update the known variables.

Test Input and Measurement Standard

The sensors will be given known concentrations of gases. Using the calibrated design, it should utilize these known inputs and use the sample mean principle to calculate the air quality properly.

Refer back to the display module, where the LCD will display the calculated index. Compare these values with the known concentrations.

Pass criteria

The test is passed if the LCD and LEDs display the same air quality measurement as the one known before the test.

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