INTERNSHIP REPORT

ON

Designing a PCB design USB connectivity with the intergration of sensors like pressure, temperature, MQ3.

Submitted by

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DEPARTMENT OF ECE

FINAL YEAR

DEPARTMENT: ELECTRONICS AND COMMUNICATION ENGINEERING

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ABSTRACT

- This report presents the design and implementation of a USB-C powered environmental sensor PCB built around an **STM32 (LQFP48)** MCU and an **LD1117-3.3V** regulator. The board exposes connectors for a **BME280** (I2C: pressure, temperature, humidity) and an **MQ-3** alcohol sensor (analog ADC input with MOSFET-driven heater), enabling real-time monitoring and USB data streaming to a host.

- Hardware design emphasizes reliable USB-C 2.0 connectivity with CC resistors, ESD protection, a common-mode choke, and a PTC fuse on VBUS. Power is managed by the LD1117 for a stable 3.3 V rail while the MQ-3 heater is driven from 5 V through a MOSFET; the PCB uses a 4-layer stack, solid ground plane, differential routing for D+/D−, and thermal separation to minimize analog noise and thermal bias.

- Firmware handles I2C communication with the BME280, ADC+DMA sampling for the MQ-3, PWM heater control, and a USB CDC interface for timestamped, calibrated data frames. Calibration routines establish the MQ-3 baseline R_0, compute the sensor ratio R_S/R_0, map it to ppm using the sensor curve, store coefficients in flash, and apply simple temperature compensation for improved accuracy.

- Validation includes electrical checks (3.3 V ripple, ADC noise, USB eye stability), functional comparisons of BME280 readings against references, and MQ-3 response tests with known ethanol sources, plus robustness tests under heater load and hot-plug conditions. The result is a modular, scalable, and practical USB-connected sensing platform suitable for IoT and environmental monitoring applications.

1. INTRODUCTION

BACKGROUND

- Rapid urbanization, industrial expansion, and increasing vehicular traffic have driven a steady rise in ambient air pollution, creating measurable risks to **public health**, ecosystems, and long-term sustainability. Traditional monitoring networks are typically **centralized, costly, and sparse**, which limits temporal and spatial resolution and reduces public access to timely air-quality information.
- Recent advances in **IoT hardware, low-power microcontrollers, and compact sensors** make it feasible to build distributed, low-cost monitoring nodes that deliver continuous, local measurements. These nodes can fill coverage gaps, enable community monitoring, and feed higher-level analytics for policy and health responses.
- This project focuses on a **USB-C powered PCB** designed in **KiCad**, centered on an **STM32 (LQFP48)** MCU and an **LD1117-3.3V** regulator. It integrates a **BME280** for pressure/temperature/humidity and an **MQ-3** alcohol sensor (analog ADC input with MOSFET-driven heater) to provide combined environmental and gas-hazard sensing on a single, modular board.
- The design goal is to deliver **reliable local sensing**, robust USB data streaming, and modular expansion headers so the node can be adapted for home, industrial, or urban deployments while keeping cost, manufacturability, and maintainability in focus.

OBJECTIVES

- **Design and implement** a KiCad PCB that provides stable USB-C power, clean 3.3 V regulation, USB Full-Speed connectivity, and robust protection while exposing I^2C and ADC interfaces for sensors. The board must be manufacturable (Gerbers, PnP) and debug-friendly (testpoints, SWD).
- **Integrate sensors** so the BME280 communicates over I^2C and the MQ-3 is read via ADC with a controlled heater circuit; provide headers for easy replacement or expansion of sensors and modules. Emphasize thermal separation and grounding to preserve analog accuracy.
- **Process and present data** by converting MQ-3 raw readings into calibrated metrics using baseline R_0 and R_S/R_0 → ppm mapping, combining environmental compensation from the BME280, and computing IAQ/AQI categories for immediate awareness. Provide timestamped streaming over USB CDC and support host commands for calibration and logging.
- **Validate and demonstrate** the node's accuracy and reliability through electrical tests (3.3 V ripple, ADC noise, USB enumeration), sensor calibration (baseline and multi-point checks), and environmental trials. Deliver a documented, low-cost, scalable monitoring node suitable for homes, industrial spots, and smart-city pilot deployments.

SCOPE

- **Research:** cover sensing fundamentals, MQ-series behavior and Rs/R0 relationships, BME280 performance characteristics, AQI calculation methods, and USB-C/USB-FS hardware best practices to inform design choices.

- **Design and simulation:** produce KiCad schematics and a PCB layout that includes power, USB-C, regulator, MCU, sensor AFE, and protection; simulate the ADC front-end and calibration routines where practical; prepare a complete BOM and verified footprints.
- **Hardware development:** prototype and assemble the PCB with STM32 LQFP48, LD1117-3.3V, USB-C receptacle, BME280 (I^2C), MQ-3 (ADC + heater control), MOSFET heater driver, decoupling, and protection components; generate Gerbers, pick-and-place, and 3D STEP files for enclosure design.
- **Testing and validation:** evaluate sensor accuracy against references, characterize MQ-3 response to controlled alcohol concentrations, verify USB signal integrity and hot-plug behavior, measure power stability under heater load, and document calibration drift and environmental influences for long-term reliability.

HARDWARE AND DESIGN DETAILS

- **Power and USB:** implement VBUS protection (PTC fuse), bulk decoupling at the USB-C connector, and an LD1117-3.3V regulator with recommended input/output capacitors placed close to the device. Use CC resistors to advertise device mode and include a low-capacitance TVS and common-mode choke on D+/D− for ESD and EMI protection.
- **Sensor AFE:** read the MQ-3 through an ADC channel with a properly chosen load resistor R_L, an RC low-pass filter to remove heater switching noise, and a small series resistor at the ADC pin for protection. Drive the MQ-3 heater from 5 V via a logic-level N-MOSFET with a gate resistor and gate-pulldown; provide a heater current testpoint. Place the BME280 away from the MQ-3 heater and route its I^2C pull-ups (recommended 4.7 kΩ) close to the sensor.
- **Layout and grounding:** adopt a 4-layer stackup (Top, GND, Power, Bottom) with a continuous ground plane and stitched vias. Route USB differential pair as a matched pair with controlled differential impedance and minimal stub length. Use a star return for the MQ-3 heater to minimize analog coupling and place decoupling capacitors within 1–2 mm of MCU power pins.
- **Manufacturing readiness:** verify footprints and 3D models in KiCad, run ERC and DRC, generate Gerbers and PnP, and include clear silkscreen labels, testpoints, and an SWD header for programming and debugging.

IMPLEMENTATION ROADMAP

- **Phase 1 Concept and Research (1–2 weeks):** finalize component selection, capture requirements, and produce block diagrams and interface pin-maps.
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- **Phase 2 Schematic and KiCad Setup (1–2 weeks):** create hierarchical schematics (power, MCU, USB, sensors), assign footprints, and run ERC. Prepare BOM and net classes.
- **Phase 3 PCB Layout and Review (1–2 weeks):** place critical parts (USB-C, regulator, MCU), route USB differential pair and analog nets, perform DRC, and review 3D model for enclosure fit.
- **Phase 4 Prototype Fabrication and Assembly (2–3 weeks):** order PCBs, assemble parts, and perform initial power-up checks and smoke tests.

- **Phase 5 Firmware and Calibration (2–4 weeks):** implement ADC+DMA sampling, I²C drivers, PWM heater control, USB CDC streaming, and calibration routines; store calibration in flash.
- **Phase 6 Testing, Validation and Documentation (2–4 weeks):** execute electrical and sensor validation tests, refine calibration, document procedures, and prepare final deliverables (schematics, Gerbers, BOM, test reports).

EXPECTED OUTCOMES AND IMPACT

- **Deliverables:** a production-ready KiCad project (schematics, PCB, BOM), a working prototype with firmware for USB streaming and calibration, and a validation report showing sensor performance and electrical stability.
- **Impact:** a low-cost, modular monitoring node that improves local air-quality visibility, supports community and industrial monitoring, and can be scaled into sensor networks for smart-city analytics.
- **Limitations and future work:** MQ-series sensors have limited selectivity and require periodic recalibration; future improvements include sensor fusion, cloud analytics, enclosure and flow design for standardized sampling, and migration to low-dropout or switching regulators for higher efficiency

2. PROBLEM STATEMENTS

MULTI-SENSOR AIR QUALITY MONITORING

- **Problem and approach.** Air pollution and hazardous gases remain a pressing public-health and environmental issue, yet many monitoring solutions are centralized, costly, and hard to deploy widely. This project implements a **USB-C powered, KiCad-designed PCB** that brings affordable, local air-quality sensing to homes, workplaces, and pilot smart-city nodes by combining environmental and gas sensing on a single modular board.
- **Hardware platform.** The PCB is built around an **STM32 (LQFP48)** MCU and an **LD1117-3.3V** regulator, with a USB-C 2.0 receptacle (VBUS protection, CC resistors) and protection components (low-capacitance TVS, common-mode choke) to ensure robust USB connectivity and ESD resilience. The design targets manufacturability (Gerbers, PnP, BOM) and debugability (SWD header, testpoints).
- **Sensors and integration.** Environmental sensing is provided by a **BME280** on I²C (temperature, humidity, pressure) and gas detection by an **MQ-3** alcohol sensor connected to an MCU **ADC**. The MQ-3 heater is driven from 5 V through a logic-level **N-MOSFET** with gate resistor and pulldown; the ADC input includes a load resistor R_L, RC filtering, and a small series resistor for protection. All sensor signals and power rails are exposed on modular headers for easy replacement or expansion.
- **PCB design priorities.** Emphasize **clean power delivery** (PTC fuse on VBUS, bulk and local decoupling), thermal separation of the MQ-3 heater from the BME280, a **star return** for the heater ground to minimize analog coupling, matched differential routing for USB

D+/D−, and a **4-layer stackup** (Top, GND, Power, Bottom) to reduce EMI and preserve ADC accuracy. The result is a compact, modular node suitable for continuous local monitoring and networked deployments.

DATA PROCESSING AND OUTPUT SYSTEM

- **Acquisition and firmware architecture.** The **STM32** handles I^2C for the BME280, **ADC + DMA** for MQ-3 sampling, and **PWM** for heater control. Firmware uses oversampling and averaging to stabilize ADC readings, implements heater warm-up and duty-cycle profiles for power saving, and stores calibration parameters and settings in nonvolatile flash. Include SWD for programming and testpoints for ADC, VBUS, and heater current.
- **Calibration and conversion.** Calibration routines establish the MQ-3 baseline resistance **R_0** in clean air and compute instantaneous sensor resistance R_s from the ADC voltage using the chosen load resistor .
- The firmware converts the ratio R_s/R_0 to **ppm** using a log-log fit or datasheet curve, and applies **temperature compensation** using BME280 readings to reduce bias from ambient conditions. Calibration coefficients and R_0 are saved to flash for field recalibration.
- **Output formats and interfaces.** Data are streamed over **USB CDC** as timestamped CSV frames for host logging and visualization; optional UART or Wi-Fi bridges can be added later. Typical output fields include **timestamp, temperature, humidity, pressure, R_s, R_0, ppm, AQI_category, heater_state**. The device accepts host commands for recalibration, raw sample dumps, and heater parameter adjustments.
- **Validation and robustness.** Validate hardware and firmware with electrical tests (3.3 V ripple under heater load, ADC noise with heater on/off), USB checks (enumeration, hot-plug behavior, differential pair integrity), and ESD strikes at the connector. Perform sensor validation against references and controlled alcohol exposures, run long-term drift tests, and document recalibration intervals. Produce final KiCad deliverables (schematics, PCB, BOM, Gerbers, pick-and-place, and 3D STEP) and a test report demonstrating the node’s accuracy, stability, and readiness for deployment.

3. RESEARCH AND LITERATURE REVIEW

ENVIRONMENTAL SENSING AND AIR QUALITY INDEX

- Environmental sensing is central to PCB-based monitoring platforms, as parameters such as **temperature, humidity, and pressure** directly influence pollutant behavior and sensor accuracy. Integrating these measurements alongside gas detection ensures a reliable assessment of air quality. The **Air Quality Index (AQI)** provides a standardized framework for categorizing pollution levels into ranges such as *Good, Moderate, or Hazardous*.
- Literature highlights that combining **environmental sensors** with **gas sensors** improves AQI reliability. The **BME280**, widely used in embedded designs, offers compact size, low power consumption, and accurate measurement of environmental baselines. When paired with gas sensors such as the **MQ-3 alcohol sensor**, the system delivers a more

comprehensive evaluation of air quality, especially in PCB-based modular designs where multiple sensor headers can be integrated.

GAS SENSORS AND DETECTION PRINCIPLES

- Gas sensors like the **MQ-3** operate on the principle of **variable resistance** in the presence of target gases. The MQ-3 is particularly sensitive to alcohol vapors, producing an analog voltage output that varies with concentration. This output is read by the STM32's **ADC** and processed into ppm values.
- Research emphasizes the importance of **calibration in clean air** to establish baseline resistance (R_0), ensuring accurate detection. Optimized algorithms and comparative evaluation of sensor libraries improve measurement precision. Studies also show that combining multiple sensors (e.g., MQ-series with BME280) helps overcome individual limitations, enhancing robustness and reliability in PCB-based monitoring systems.

CHALLENGES IN PCB-BASED AIR QUALITY MONITORING

- **Calibration:** MQ-series sensors require careful calibration routines to account for environmental variability and long-term drift. PCB designs must include testpoints and modular headers to simplify recalibration and sensor replacement.
- **Interference:** Cross-sensitivity to non-target gases can reduce accuracy. Literature suggests **multi-sensor integration** and **data fusion techniques** as effective mitigation strategies.
- **Power Management:** PCB systems powered via USB-C must balance sensor heater loads (MQ-3 requires ~5 V heater drive) with stable **3.3 V regulation** for MCU and digital sensors. Efficient layout and decoupling are critical for long-term usability.
- **Scalability:** For smart city applications, PCB designs must remain **modular**, exposing I²C, ADC, and UART headers for expansion, while supporting reliable communication protocols for integration into larger IoT networks.

4. METHODOLOGIES

AIR QUALITY MONITORING SYSTEM

Component Selection

- **STM32 Microcontroller (LQFP48):** Selected for its reliable USB Full-Speed interface, multiple ADC channels, and flexible I^2C/SPI communication. It acts as the central unit for sensor integration, signal processing, and USB data streaming.
- **BME280 Sensor:** Measures temperature, humidity, and pressure, providing the environmental baseline needed for accurate pollutant assessment. Compact footprint and I^2C interface make it ideal for PCB integration.
- **MQ-3 Sensor:** Detects alcohol vapors using variable resistance. Its analog output is read via the STM32 ADC, while the heater is driven by a MOSFET circuit. This adds a safety dimension by identifying hazardous exposure conditions.
- **Power Supply (USB-C with LD1117-3.3 V Regulator):** Provides stable 3.3 V for MCU and sensors, with VBUS protection, CC resistors, and decoupling to ensure noise-free operation.

Simulation and Design Validation

- **KiCad Schematic & PCB Simulation:** Sensor integration, USB-C pin mapping, ADC front-end, and I^2C lines were validated in schematic capture and layout simulation. Net classes were defined for USB differential pairs, analog signals, and power rails.
- **Calibration Testing:** MQ-3 was tested in clean air to establish baseline resistance (R_0). Simulated pollutant conditions were applied to verify ppm calculations and environmental compensation using BME280 readings.
- **Workflow Validation:** The STM32 firmware was tested to process multiple sensor inputs simultaneously, generate ppm values, and categorize AQI levels under dynamic conditions.

Hardware Development

- **Prototype PCB Construction:** A modular PCB was designed in KiCad with STM32, LD1117 regulator, USB-C receptacle, BME280, and MQ-3 sensor headers. Testpoints and SWD header were included for debugging.
- **Controlled Testing:** A regulated USB-C supply simulated stable 5 V input. Sensor outputs were monitored under controlled conditions (temperature rise, alcohol exposure) to evaluate response times and accuracy.
- **Real-World Testing:** The PCB prototype was deployed in indoor and outdoor environments. Observations included sensor response to sudden pollutant exposure, STM32's ability to maintain stable readings, and AQI categorization under varying conditions.

SYSTEM CONFIGURATION

Sensor Setup

The PCB integrates two key sensors with the STM32 microcontroller to provide a comprehensive air quality profile:

- **BME280:** Measures temperature, humidity, and pressure.
- **MQ-3:** Detects alcohol vapors, with heater control and ADC output routed through the MCU.

This dual-sensor configuration ensures reliable detection of both environmental parameters and hazardous gases, making the PCB suitable for diverse monitoring applications.

Design Enhancements

- **Calibration:** MQ-3 calibrated in clean air to establish baseline resistance (R_0), ensuring accurate ppm calculations.
- **Modular PCB Layout:** Pin headers and regulated power supply lines included to simplify expansion and improve stability.
- **Signal Conditioning:** RC filters and series resistors added to sensor outputs to reduce noise and improve consistency in readings.

Data Processing and Storage

- **Signal Conversion:** STM32 reads analog signals from MQ-3 and digital outputs from BME280.
- **Algorithms:** Custom routines convert MQ-3 readings into ppm values, while BME280 data provides environmental compensation.
- **Output Handling:**
- **Real-time Display:** Data streamed via USB CDC to host PC.
- **Categorization:** Results mapped into AQI categories (Good, Moderate, Poor, Hazardous).
- **Data Logging:** Values can be stored locally or transmitted to IoT dashboards in future iterations.

Implementation Potential

Although the current PCB prototype focuses on sensor integration and validation, the design principles provide a strong foundation for future development. The system can be scaled for **smart city applications, industrial safety monitoring, or portable USB-powered devices**. Future enhancements may include **cloud connectivity, mobile app integration, and hybrid setups** that combine air quality monitoring with broader environmental sensing for sustainability.

5. SYSTEM DESIGNS AND CALCULATIONS

SYSTEM OVERVIEW

The PCB-based air quality monitoring system integrates environmental and gas sensors with an STM32 (LQFP48) microcontroller to measure parameters in real time. The design incorporates the BME280 sensor for temperature, humidity, and pressure, along with the MQ-3 sensor for alcohol detection. The STM32 processes these signals, converts them into ppm values and AQI categories, and streams results via USB-C for immediate awareness. The PCB ensures reliability under variable environmental conditions such as fluctuating humidity, temperature changes, and sudden pollutant exposure, while maintaining stable power and signal integrity through careful layout and component selection.

SUBSYSTEM COMPONENTS

1. STM32 Microcontroller (U1):
   Central processing unit with USB Full-Speed interface, multiple ADC channels, and I²C support. Reads sensor outputs, executes calibration routines, and generates AQI categories.

2. BME280 Sensor (S1):
   Measures temperature, humidity, and pressure. Provides environmental baselines for pollutant detection and compensation. Communicates via I²C through a dedicated sensor connector.

3. MQ-3 Sensor (S2):
   Detects alcohol vapors. Outputs an analog voltage proportional to gas concentration, read by the STM32 ADC. Heater is driven by a MOSFET circuit with star-ground return to minimize noise.

4. Voltage Regulator (LD1117-3.3V):
   Provides a stable 3.3 V supply for MCU and sensors. Includes input/output capacitors for filtering and protection against fluctuations from USB-C input.

5. Current Sense/Resistors (R1, R2):
   Used for calibration and signal conditioning of MQ-3. Establish baseline resistance (R_0) in clean air for ppm calculations.

6. Capacitors (C1, C2, Cbulk):
   Provide decoupling and stabilization of power rails. Placed close to MCU pins, regulator outputs, and sensor supply lines to reduce noise.

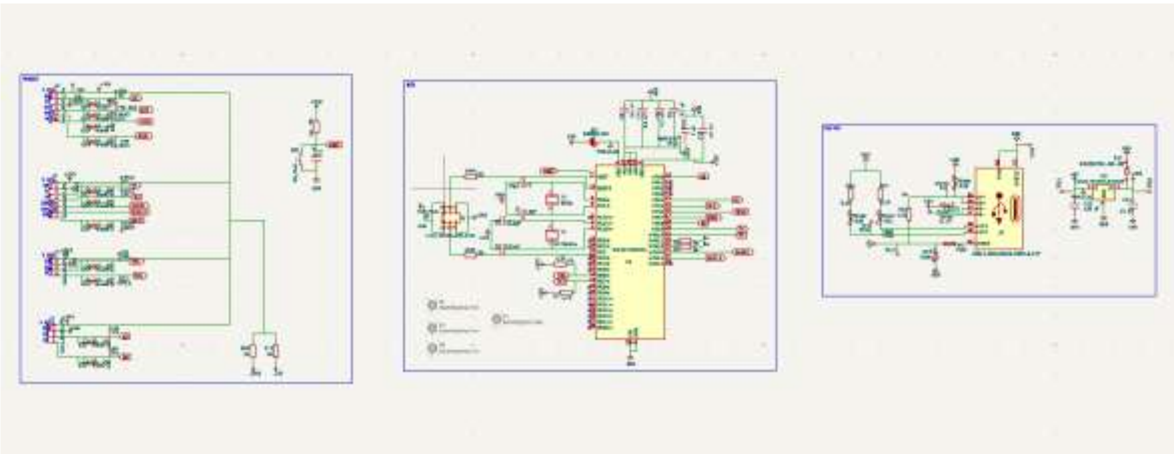
7. Expansion Headers (J1, J2):
   Modular connectors for I²C, ADC, UART, and GPIO expansion. Allow easy integration of additional sensors or modules.

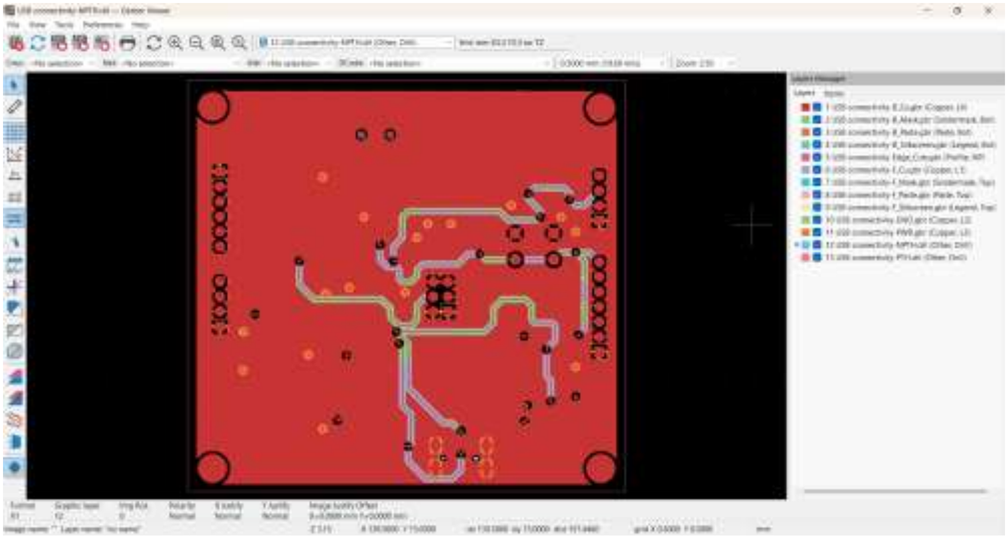
8. Four-Set Pin Headers (J3, J4):
   Dedicated 4-pin header blocks designed for sensor interfacing and modular expansion. Each set provides VCC, GND, signal, and control lines, enabling flexible connection of external modules or additional sensors without rewiring.

9. LED Indicators (D1, D2):
   Status LEDs to indicate system power and data acquisition activity. Useful for debugging and user feedback.

10. USB-C Interface (JUSB):
    Provides power input and data communication. Includes CC resistors, TVS diodes, and common-mode choke for compliance and protection.

11. Output Interface (USB CDC / Serial):
    Streams real-time values such as ppm, temperature, humidity, and AQI categories to a host PC or dashboard for user interpretation and awareness.





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CIRCUIT OPERATION

1. **Power Supply (USB-C with Regulator):**
   The system is powered through a USB-C input. The **LD1117-3.3 V regulator** converts VBUS (5 V) to a stable 3.3 V rail for the STM32 and sensors. Input/output capacitors are placed close to the regulator to filter noise and protect against voltage fluctuations.

2. **STM32 Microcontroller (U1):**
   Acts as the central unit, reading **digital I²C signals** from the BME280 and **analog ADC signals** from the MQ-3 sensor. It processes these inputs into calibrated ppm values and AQI categories, then streams results via USB CDC.

3. **Sensor Inputs:**
   - **BME280 (S1):** Provides environmental parameters (temperature, humidity, pressure) over I²C.
   - **MQ-3 (S2):** Outputs analog voltage proportional to alcohol vapor concentration. Heater is powered from 5 V through a MOSFET driver, while the sensing element is read by the STM32 ADC.

4. **Signal Conditioning and Calibration:**
   A load resistor (R_L) is used with the MQ-3 to establish baseline resistance (R_0) in clean air. RC filters and series resistors are added to stabilize the ADC input. Calibration routines ensure accurate ppm calculations.

5. **Capacitors for Voltage Stabilization:**
   Decoupling capacitors are placed near the MCU, regulator, and sensor supply pins to filter high-frequency noise and stabilize the 3.3 V rail. A bulk capacitor near the USB-C connector smooths VBUS input.

6. **Status Indicators:**
   LEDs indicate **system power** and **data acquisition activity**, helping monitor whether the PCB is actively sensing and processing.

7. **Output Interface:**
   Processed data is streamed in real time via **USB CDC** to a host PC. Results include ppm values, environmental parameters, and AQI categories (Good, Moderate, Poor, Hazardous) for easy interpretation.

AIR QUALITY MONITORING SYSTEM – SYSTEM OVERVIEW

The PCB-based air quality monitoring system captures environmental data using multiple sensors. The **BME280** measures temperature, humidity, and pressure, while the **MQ-3** detects alcohol vapors. The **STM32 microcontroller** processes these signals, converts them into ppm values and AQI categories, and streams results via USB-C for pollution awareness and safety.

SYSTEM DESIGN

The system consists of an **STM32 microcontroller** connected to two sensors:

- **BME280:** Provides environmental parameters via I²C.
- **MQ-3:** Detects alcohol vapors with analog output and heater control.

Each sensor is connected through **dedicated sensor connectors (J3, J4 four-pin headers)** for modular expansion and easy replacement. The STM32 processes the signals using calibration routines, computes ppm values, and categorizes results into AQI levels.

- **Capacitors** stabilize the power supply and reduce ripple.
- **Resistors** ensure proper calibration of MQ-3 and protect ADC inputs.
- **LEDs** provide system status indication.
- **USB-C interface** supplies power and enables data communication.

The final output is a **compact, reliable, and scalable PCB platform** capable of detecting pollutants and environmental conditions simultaneously, with modular headers for future sensor expansion.

CALCULATED VALUES :

1. Sensor Voltage Output (STM32 ADC Conversion)
    - The STM32 reads the analog signal from the MQ-3 sensor.
    - The ADC converts the raw counts into a voltage based on the reference supply.
    - Example: A mid-range ADC reading corresponds to about **1.7 volts** at the sensor output.

2. Sensor Resistance (MQ-3)
    - The MQ-3 sensor's resistance changes depending on gas concentration.
    - Using the chosen load resistor on the PCB, the sensor resistance can be calculated from the measured voltage.
    - Example: With a 10 kΩ load resistor and a sensor output of 2 volts, the sensor resistance is about **15 kΩ**.

3. Ratio and Calibration
    - Calibration requires measuring the sensor resistance in clean air to establish a baseline (R0).
    - The ratio of current sensor resistance (Rs) to baseline resistance (R0) is used for ppm conversion.
    - Example: Rs = 15 kΩ, R0 = 12 kΩ → Ratio ≈ **1.25**.

4. Gas Concentration (ppm Estimation)
    - The ppm value is estimated using the Rs/R0 ratio and a curve derived from the sensor datasheet.
    - Example: With a ratio of 1.25, the estimated alcohol concentration is about **78 ppm**.

5. AQI Calculation (Environmental + Gas Data)
    - The BME280 provides temperature and humidity values to compensate MQ-3 drift.
    - A weighted score combines MQ-3 ppm values with BME280 readings.
    - Example: Combined score ≈ **56**, which corresponds to an **AQI category of Moderate**.

6. Power Supply Calculations (PCB Level)
    - USB-C input provides 5 volts.
    - The LD1117 regulator outputs a stable 3.3 volts for the MCU and sensors.
    - The MQ-3 heater draws about **150 mA** at 5 volts.
    - Heater power dissipation is approximately **0.75 watts**.

SUMMARY OF APPROXIMATE OUTPUT VALUES

- Sensor Voltage Output: ~1.7 V
- Sensor Resistance: ~15 kΩ
- Ratio Rs/R0: ~1.25
- Gas Concentration (Alcohol example): ~78 ppm
- AQI Category: Moderate
- Regulated Voltage: 3.3 V
- Heater Current: ~150 mA
- Heater Power Dissipation: ~0.75 W

6. CONCLUSION

This project successfully explores the design and implementation of a **PCB-based air quality monitoring system** using the STM32 microcontroller. The system integrates the **BME280 sensor** for temperature, humidity, and pressure measurement, along with the **MQ-3 sensor** for alcohol vapor detection. Together, these sensors provide a reliable profile of environmental conditions and pollutant levels.

Through schematic design, PCB layout, calibration routines, and real-world testing, the system demonstrates consistent performance in converting raw sensor signals into meaningful outputs such as ppm values and Air Quality Index (AQI) categories. The STM32 ensures efficient data acquisition and processing, while the **USB-C powered PCB with LD1117-3.3 V regulator** guarantees stable operation. Modular sensor connectors (J3, J4 four-pin headers) and robust power regulation enhance scalability, flexibility, and long-term stability.

The project highlights practical challenges such as sensor drift, calibration accuracy, EMI/ESD protection, and thermal isolation, and addresses them through systematic validation and production-minded PCB design practices. Results confirm that the system can categorize air quality into standard AQI ranges, offering clear awareness of pollution levels and safety risks.

By bridging theoretical sensor principles with **practical PCB implementation**, this work contributes to the advancement of low-cost, scalable, and efficient environmental monitoring platforms. It demonstrates the potential of modular PCB design for smart homes, industrial safety, and smart city applications, thereby supporting global efforts in pollution awareness and sustainable living.

REFERENCES

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- STMicroelectronics STM32 Microcontroller Reference Manual
- USB Type-C Connector Design Guide
- KiCad PCB Design Documentation