# Design and Implementation of an Automated Odor-Controlled Smart Waste Bin with Real-Time Monitoring Using Arduino Nano

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## ABSTRACT

The purpose of this paper was to describe the design and implementation of a low-cost, automated smart waste bin that uses sensors to monitor and improve both the cleanliness of homes and the environment in real-time. It also has the function of providing an effective, hands-off method of disposing of trash and automatically removing odors from the environment. The primary components of the system are the Arduino Nano microcontroller and the multi-modal sensor array connected to it. The Arduino Nano allows users to have a low-cost option for controlling how their smart trash can works. The ultrasonic proximity sensor enables touchless access to the smart trash can. In addition, the internal ultrasonic waste sensor continuously monitors the amount of waste in the can so that users can know when it needs to be emptied. The VOCs detected by the internal odor sensor will trigger the high-velocity blower fan to blow the bad smells out of the smart trash can using the IRFZ44N MOSFET driver. Users receive feedback from the HMI (Human-Machine Interface), which includes the I2C-enabled LCD display and the "Traffic Light" LED indicator system, about whether or not the air quality is good or bad and if the smart trash can needs to be emptied. Experimental testing showed that the system can respond appropriately to maintain a clean home environment by using its various automated functions and air purification functions.

**Keywords:** Smart Trash Bin, Odor-control, Gas Detection, Audio-Visual Feedback

## INTRODUCTION

Residential waste management is still a major public health problem because organic materials are decomposing so rapidly [1]. Primary sources of indoor air pollutants which can cause serious health problems with VOCs and bio-aerosols include traditional, manually opened or closed waste receptacles [2]. Additionally, the manual operation of the lid on a trash bin creates additional hygiene risk as this action will increase the chance of transference of pathogens when physically touching the lid [3].

The rapid changes facing the current waste management system have stimulated a new area of research focused on creating “Smart Waste Management” systems which use an embedded technological environment for environmental data collection and monitoring [4]. Recent studies, such as those by Mahajan and Kokane (2017), have shown that the integration of Internet of Things (IoT) sensors into a waste management system is capable of providing users with real time updates about the amount of waste being generated within each region, as well as the local environmental conditions [5]. At the same time, researchers are also developing alternative methods of activating waste processing systems without direct physical contact, including the use of ultrasonic proximity sensing to reduce contamination risk and enhance user experience in domestic environments [7].

Although there have been improvements in the development of smart bins that monitor the level of filling for logistical purposes and do not address the need for active odor removal, [6, 8] this research proposal will focus on developing a low-cost, stand-alone sensor-based system that utilizes an Arduino Nano to provide real-time atmospheric data as well as high current to control the operation of a mechanical blower fan used for VOC removal when those VOCs are detected by the sensors. This research study has addressed the deficiency in indoor air purification inside waste receptacles and created an affordable and independent means of increasing home cleanliness without needing expensive IoT networks.

### Importance and Relevance of the Study

This study was an important one because it provided an example of how to create an automated waste management system (as designed and built) that would be able to continuously monitor the environment and use commercially available parts at a relatively low cost. As such, by combining both high current actuators and high-end atmospheric sensors in a single unit, this study offers a real-world application of a system that can make logic based decisions on its own in real time, while still being embedded in an environment using the Arduino Nano and MQ-series gas sensors; therefore, this project is an excellent example of a high fidelity functional prototype for improving indoor air quality and reducing the risk of decomposing waste.

The results of this research will assist students and researchers in both Computer Engineering and Electronics Engineering by providing a real-world lab experience in three key areas: robotics, atmospheric sensing, and power electronics. In addition to offering a practical example of managing inductive loads and achieving power isolation through the use of an IRFZ44N MOSFET for high current switching, this study also serves as a reference resource for labs with multiple experiments; specifically including sensor calibration, multi-state logic loops, and Human-Machine Interfaces (HMIs). Additionally, the modularity of the system will allow it to be updated and expanded to accommodate future experiments, for instance, connecting it to the internet via an IoT device so that data collected can be logged to the "cloud" or automating waste sorting mechanisms.

Beginning with its contributions to education, this study has also contributed to the expanding body of research related to smart cities and sustainable urban design. This project presents a cost-effective, decentralized method for localizing waste treatment and odors as it addresses a critical gap in logistics in today's sanitary methods. This project can be applied to many high-risk environments, such as hospital waste management, because the use of a touchless user interface prevents the risk of cross-contamination, which would compromise public safety. Furthermore, the technology in this project will have direct applications to office sanitation and smart home automation, and demonstrates the wide range of possibilities that embedded systems can provide to create smart, clean, healthy, and environmentally sustainable platforms.

## REVIEW OF RELATED LITERATURE

This chapter will present an analysis of the literature and available technology related to smart waste management. The literature has been grouped into four thematic categories: Smart Trash Bins, Odor control, Gas detection, and Audio-Visual feedback systems.

### Smart Trash Bin

Research by Navghane et al. (2016) has developed an initial design model for fully automated garbage tracking using an Arduino microcontroller. The research of Navghane et al. (2016) is illustrative as it demonstrates how the automation of contact between humans and trash cans can greatly reduce bacterial transmission and optimize the timing of waste collection. It was found by the authors that a "smart bin" would be effective in maintaining the cleanliness of households when it functions completely automatically and hands-off [6].

### Odor-control Mechanisms

The literature review conducted by Hannan et al. (2015) provided an overview of the technologies that have been used in the management of decomposing solid waste. Their review identified the need for both containment and active management of the by-products of waste decomposition to avoid contamination of the environment. This literature review indicates that an active response mechanism, i.e., localized ventilation, could be employed to reduce the odor and air quality hazards caused by the decomposition of organic matter [1]

### Gas Detection Technologies

An investigation by Kodali and Sahu (2016) identified how MQ-series semiconductor sensors could be used in an embedded system to monitor urban waste environments through the detection of organic decay through unique chemical signatures, specifically, ammonia and methane, utilizing analog voltage levels to determine "fresh" and "hazardous" air quality zones.

**Audio-Visual Feedback and Monitoring**

The study conducted by Mahajan and Kokane (2017), examined the implementation of smart management systems to monitor the atmosphere in waste bins and assess the changes to the environment. Through their analytical findings, they show that the integration of gas-detecting sensors in monitoring waste decomposition will allow for quicker interventions to prevent potential harm to the environment. These results demonstrate the capability of utilizing sensor data as an indicator to implement active maintenance procedures.

Table 1. Comparison Matrix of Related Studies and Current Research

| Study | Smart Trash Bin | Odor-control Mechanisms | Gas Detection Technologies | Audio-Visual Feedback |
|---|---|---|---|---|
| Navghane et al. (2016) | Implemented an automated monitoring system using Arduino. | | Used ultrasonic sensors for physical level sensing | Utilized simple alerts for collection logistics. |
| Saini and Kaur (2018) | | Utilized active ventilation to reduce toxic gas buildup. | Integrated MQ-series sensors to trigger response. | |
| Kodali and Sahu (2016) | Developed a smart system for urban waste tracking. | | Validated MQ-135 for detecting methane and ammonia. | |
| Mahajan and Kokane (2017) | | | | Developed LCD and LED "Traffic Light" HMI feedback. |
| Current Study | Developed a standalone Arduino Nano-based platform. | Employs MOSFET-driven blower fan for VOC filtration. | Uses calibrated MQ-135 for real-time atmospheric sampling. | Integrates prioritized LCD, RGB LED, and Buzzer diagnostics. |

# METHODOLOGY

**Hardware Architecture**

**Central Controller:** An Arduino Nano is utilized for its small form factor and efficient processing of multi-sensor data.

**Actuation System:** A 180-degree SG90 micro-servo motor is used to drive the lid mechanism. For odor neutralization, a DC blower fan is controlled via an IRFZ44N N-Channel MOSFET, allowing for high-current switching from the 5V DC wall adapter.

**Sensor Suite:**

- HC-SR04 Ultrasonic (External): Detects hand proximity for lid opening.
- HC-SR04 Ultrasonic (Internal): Measures the distance to the trash to calculate "Fullness."
- MQ-135 Gas Sensor: Monitors air quality and detects foul odors.

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**HMI Unit:** A 16x2 I2C LCD displays system states ("Fresh," "Odor Detected," "Bin Full"). A Tri-color LED system (Green, Yellow, Red) provides instant visual alerts for odor intensity.

**Software Implementation**

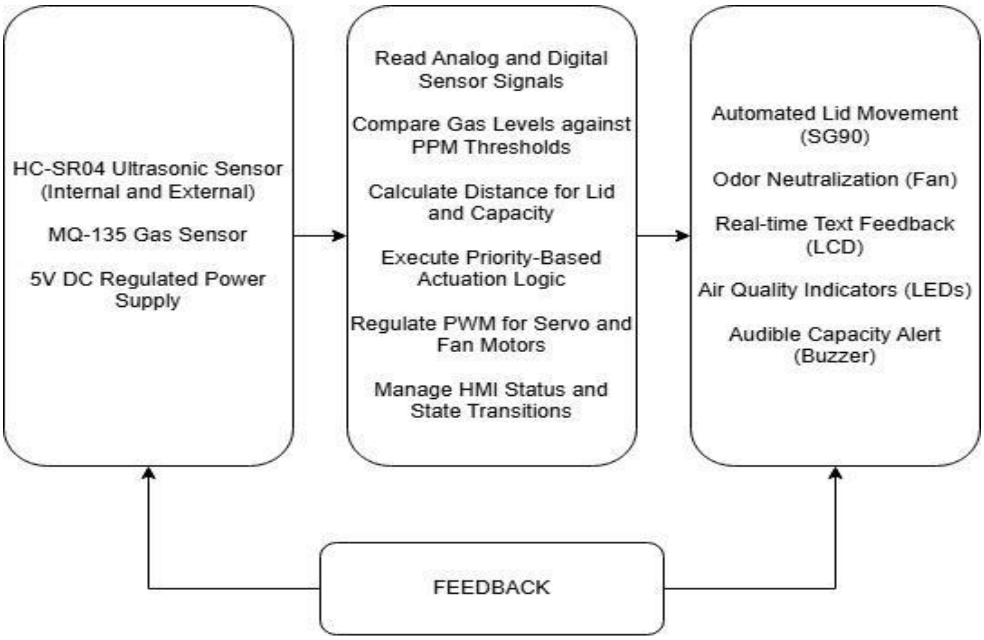
The control logic is developed in C++ using a priority-based hierarchy:

1. **Safety & Capacity:** If the internal sensor detects the bin is full, the fan is disabled to prevent dust circulation, and a buzzer alarm is triggered.

2. **Lid Control:** If a hand is detected within 20cm, the lid opens for a 4-second delay before automatically closing.

3. **Odor Neutralization:** If gas concentration exceeds 250 PPM, the fan is activated and the LED transitions from Green to Yellow/Red.

Figure 1. Input–Process–Output (IPO) Model




Smart bins utilize the principles of closed-loop systems, in which the environment can cause both the actuators to behave and provide user feedback based on direct environmental influences.

Environmental sensing occurs during the input phase. The input sensing phase includes the detection of the presence of a hand by an HC-SR04 ultrasonic sensor, which will actuate the lid of the smart bin, and another internal HC-SR04 sensor that measures how much trash is in the smart bin. A third sensor, the MQ-135, detects VOCs. Power to the system comes from a stabilized 5V DC input provided by a high-current wall plug adapter.

The Arduino Nano serves as the main processor of the system and employs a priority-based control method. The Arduino Nano reads either analog or digital signals for real-time on the sensors and generates a status report of the smart bin. Additionally, the Arduino Nano compares the values it has read with predetermined threshold values (for example, distance less than 20 cm or gas greater than 250 ppm) and determines if the smart bin should operate in one of three modes: full, odorous, or fresh. The PWM signal for the servo motor and the logic controlling whether the fan is on or off through the MOSFET are managed by the firmware.

The output stage processes the logical results of processing, producing visual or physical outputs. Movement is actuated using an SG90 micro-servos to move lids and a DC blower fan to blow air through filters. The user receives feedback from the system using a 16x2 I2C LCD, which displays textual status in real time; a "traffic

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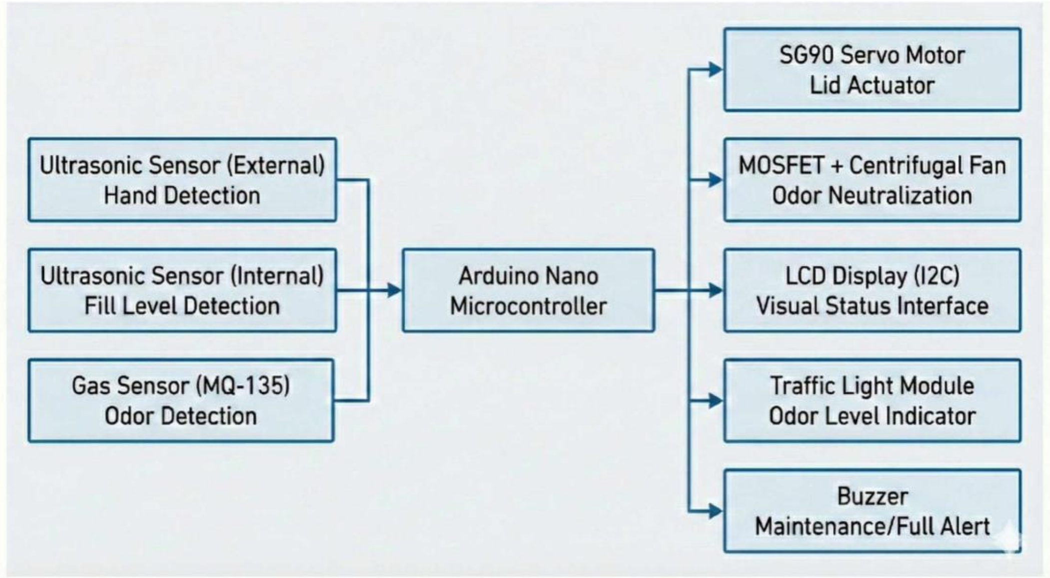
light" style LED light bar shows the air quality level, and an active buzzer gives an audible warning when the "bin full" or maintenance state has been entered.

Figure 2. Block Diagram




A system block diagram represents a graphical illustration of how the various subsystems within the project are connected to each other and represent the path that data and electrical energy will take. The Smart Odor-Controlled Waste Bin can be broken down into four distinct blocks, including the processing unit, power distribution system, input sensing array, and output actuation subsystem.

**1. Processing Unit**

The Arduino Nano microcontroller is at the center of this system, acting as a processor to handle the system's logic in real-time. The Arduino Nano is also responsible for acquiring data in real-time from the sensor array, executing control firmware, and producing PWM and digital signals to actuate the actuators. Due to its compact size and the integrated voltage regulator, the Arduino Nano was ideal for local control in this prototype.

**2. Power Distribution System**

As opposed to conventional battery-based portable electronics, the system uses a regulated 5V DC power source derived from an AC-to-DC wall adapter. The use of a regulated power source allows for a high current capability that supports the simultaneous operation of both the SG90 servo and the mechanical blower fan. The regulated power source has two primary paths: a low current path for the microcontroller and sensor circuitry, and a high current path for the mechanical actuator circuitry, to maintain a stable voltage supply and prevent logic resets caused by high-torque movement.

**3. Input Sensing Array**

The Input Subsystem provides environmental telemetry to the processing unit through three specific sensor modules:

- **External Ultrasonic Sensor:** Utilized for hand proximity detection to enable hands-free lid operation.
- **Internal Ultrasonic Sensor:** Positioned to measure the distance to the accumulated waste, providing data on the bin’s volumetric capacity.
- **MQ-135 Gas Sensor:** Provides an analog signal representing the concentration of volatile organic compounds (VOCs) and hazardous gases within the receptacle.

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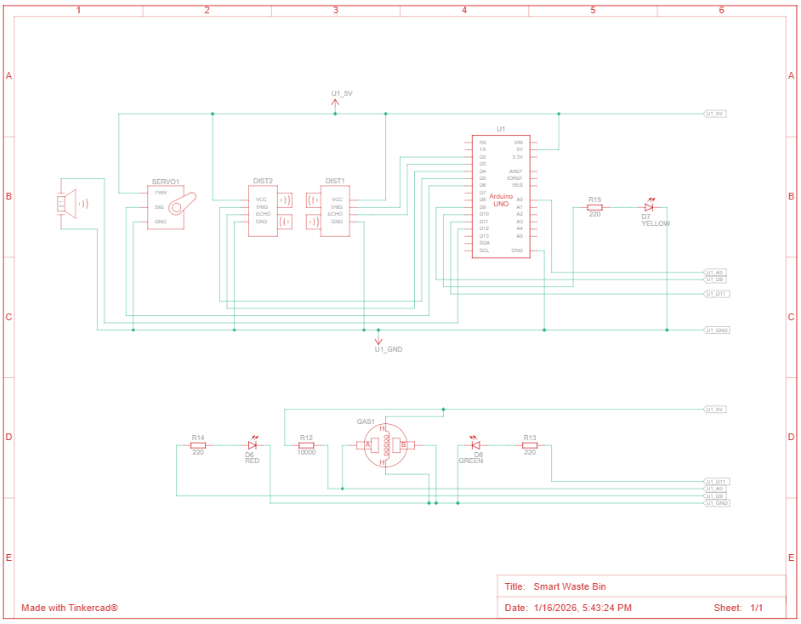
### 4. Output and Actuation Subsystem

The Output System is responsible for converting output from the Processing System to mechanical action, and for providing user input back to the system. The SG90 micro-servos control the lid of the unit, while the DC Blower Fan provides active odor neutralization, controlled via an IRFZ44N MOSFET driver. For the Human Machine Interface (HMI), we have a 16 x 2 I2C LCD that will display diagnostic messages, as well as a "traffic light" LED bar that provides a color-coded air quality indicator, and an active buzzer to alert the user with audible signals when in a state of alarm (for example, needing to replace the filter, etc.), or in case of overflow.

Figure 3. Schematic Diagram




The Full Schematic Diagram displays the entire electrical layout of the Smart Odor-Controlled Waste Bin. The Full Schematic Diagram demonstrates how each part of the sensor array communicates with one another and the processing unit as well as the high-current actuators, ensuring that data can be transmitted stably and there are no problems with the power supply of the system.

### 1. Controller and HMI Interfacing

At the core of this schematic is the Arduino Nano which serves as the central processing unit. The 16x2 LCD with I2C capabilities is connected using the SDA (Pin A4) and SCL (Pin A5), which will act as a "dashboard" for the system, providing real-time text feedback related to air quality and the current state of the bin. Utilizing the I2C protocol allows us to minimize the number of wires needed in our setup, thereby decreasing signal noise and reducing the overall size of our hardware setup.

### 2. Sensor Integration and Signal Flow

The schematic maps the distributed sensing array to the Nano's digital and analog ports:

- **Ultrasonic Sensors:** The "Lid" and "Fill" sensors utilize four digital pins (D2/D3 and D4/D5) for Trigger and Echo pulses, enabling the system to calculate proximity through time-of-flight measurements.

- **MQ-135 Gas Sensor:** This module is connected to the Analog Pin A0, providing a continuous voltage range that represents gas concentration levels.

### 3. Power Actuation and Feedback

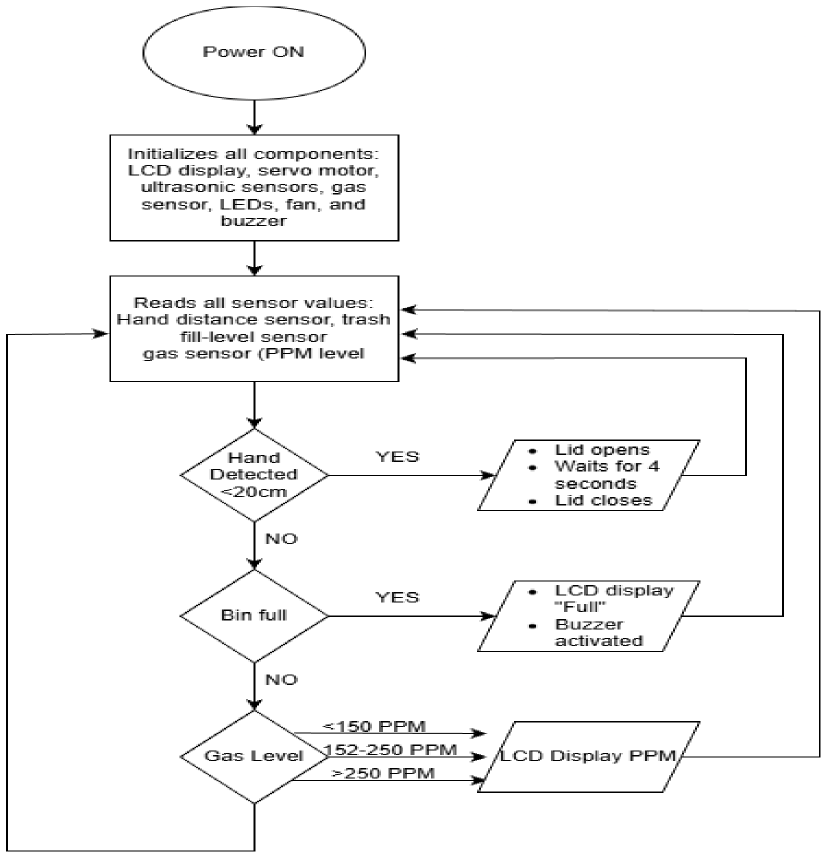
The right side of the diagram illustrates the actuation and notification components:

- **Servo Control:** The SG90 micro-servo is connected to a PWM-capable digital pin (D6), allowing for precise angular positioning of the lid mechanism.
- **Odor Neutralization:** The IRFZ44N MOSFET is configured as an electronic switch. It interfaces between a digital output pin (D7) and the high-current DC blower fan. This isolation is critical as it prevents the inductive load of the fan from damaging the microcontroller's sensitive internal circuitry.
- **Alert System:** The "Traffic Light" LEDs (Pins 9, 10, 11) and the active buzzer (Pin 12) are mapped to provide immediate visual and audible grading of the bin's status.

**4. Grounding and Stability**

All parts of the Full Schematic Diagram have an architectural common ground in order to eliminate floating signal issues. Because the MQ-135 and ultrasonic sensors require a grounded plane to accurately read the environment, this common ground is especially important for these sensors. Overall, the Full Schematic Diagram illustrates a robust embedded system where environmental input causes a logical decision that results in physical motion and diagnostic feedback from the user.

Figure 4. Flow Chart




The Smart Odor-Controlled Waste Bin's operational logic utilizes a continuous priority-based polling loop. The C++ firmware for this device will always ensure that there are no conflicts with the critical safety and hygiene functions (i.e., opening/closing the lid or alerting of an overflow) and the function to maintain the atmosphere within the bin.

**1. System Initialization**

When you connect your 5V DC power source to the Arduino Nano, it runs the setup() routine first. Within the setup() routine, the code sets up I2C communications with the LCD screen, positions the SG90 servo at 0 degrees, sets up the digital pins for all sensors and actuators, and waits for 2000 milliseconds (approximately 2

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seconds) for the MQ-135 sensor's heating elements to reach a stable temperature, so it can begin taking gas readings.

**2. Data Acquisition Stage**

In the main loop, the system simultaneously samples data from the three primary inputs:

Proximity Check: Measures distance to the nearest object via the external ultrasonic sensor.

Volumetric Check: Measures the distance to the accumulated waste via the internal ultrasonic sensor.

Gas Sampling: Reads the analog voltage from the MQ-135 sensor to determine current VOC concentrations.

**3. Decision Hierarchy and Actuation**

The system processes data based on the following hierarchy:

Lid Logic (Hygienic Priority): If an object is detected within the 20cm threshold, the microcontroller interrupts background tasks to execute the moveServo subroutine. The lid rotates to 180°, remains open for a 4-second disposal window, and then returns to the closed position.

Capacity Logic (Maintenance Priority): If the internal sensor detects trash within 10cm of the lid, the system triggers the "Bin Full" state. This activates the buzzer alarm and updates the LCD status to "FULL."

Odor Logic (Environmental Priority): If no physical triggers are active, the system evaluates air quality.

- Fresh Zone (<150 PPM): Green LED active, Fan OFF.
- Mild Odor Zone (150-250 PPM): Yellow LED active, Fan ON.
- Strong Odor Zone (>250 PPM): Red LED active, Fan ON at maximum power.

**4. Feedback Loop**

The process concludes by updating the I2C LCD and LED array with real-time diagnostic telemetry before looping back to the acquisition stage, ensuring a responsive closed-loop mechanism.

## RESULTS AND DISCUSSION

Table 2. Variables and Conditions

| Variable / Component | Type (Input / Output) | Parameter Measured / Controlled | Condition or Range | System Response / Action |
|---|---|---|---|---|
| MQ-135 Gas Sensor | Input | Atmospheric VOCs | Low (<150 PPM)<br>Medium (150-250 PPM)<br>High (>250 PPM) | Green LED; Fan OFF<br>Yellow LED; Fan ON (Med)<br>Red LED; Fan ON (High) |
| Ultrasonic Sensor (Lid) | Input | Hand Proximity | < 20 cm | Servo rotates to 180° |
| Ultrasonic Sensor (Fill) | Input | Waste Capacity | < 10 cm | LCD "FULL"; Buzzer ON |

| | | | | |
|---|---|---|---|---|
| IRFZ44N MOSFET | Output | Fan Power | Digital HIGH/LOW | High-velocity ventilation |
| SG90 Micro Servo | Output | Lid Mechanism | PWM Signal | Mechanical opening/closing |

Table 3. Performance Evaluation of the Smart Waste Bin

| Trial # | Test Material | Gas Level (Analog) | Fan Response | LED State | Outcome |
|---|---|---|---|---|---|
| 1 | Cat Feces | 368 (High) | Active (High) | RED | Successful |
| 2 | Spoiled Food | 185 (Medium) | Active (Low) | YELLOW | Successful |
| 3 | Fresh Air | 62 (Low) | Inactive | GREEN | Successful |
| 4 | Kitchen Waste | 173 (Medium) | Active (Low) | YELLOW | Successful |
| 5 | Cat Feces (Repeat) | 320 (High) | Active (High) | RED | Successful |

## CONCLUSION

The successful realization of both the design and development of the Smart Odor-Controlled Waste Bin was achieved by combining the Arduino Nano and multa i-modal sensor array. The Smart Odor-Controlled Waste Bin successfully completed testing using different types of organic waste, including cat feces, kitchen waste, and spoiled food, to demonstrate its ability to detect VOCs and activate automatic ventilation sequences. The Smart Odor-Controlled Waste Bin also successfully utilized a priority-based control logic to manage multiple functions, allowing for continuous operation of the hygienic lid function while simultaneously operating active air purification.

Technical assessments proved that the replacement of an IRFZ44N MOSFET-driven fan with a 5V regulated power source had corrected previous issues associated with system instability and excessive heat in components. The "traffic light" LED display and I2C LCD interface also served to provide the user with a clear and transparent interface for obtaining real-time information related to their environment. This project demonstrated how a low-cost, embedded system design could be used as a practical means to improve household cleanliness and indoor air quality through automated environmental sensing.

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The authors, [1]Carl Danielle C. Andante, [2]Christian E. Ladislao, [3]Lovely B. Nacional, and [4]Kyla Marie G. Septimo, are currently pursuing their Bachelor of Science degrees in Computer Engineering at the Eulogio “Amang” Rodriguez Institute of Science and Technology (EARIST), Manila, Philippines.

As a research group, their collective interests focus on the development of autonomous systems, embedded logic control, and the practical application of robotics in solving navigational problems. This project serves as a partial fulfillment of their degree requirements.