

IoT Enabled Real-Time Noise Surveillance Monitoring System

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Abstract

Noise pollution has become a critical environmental issue in urban areas, adversely affecting human health and overall quality of life. Conventional noise monitoring methods are often limited to manual measurements and fixed stations, which are costly, labor-intensive, and unable to provide real-time data. To address these limitations, the IoT-Based Noise Pollution Monitoring System has been developed, leveraging an ESP32 microcontroller, sound sensor, LCD display, buzzer, and cloud connectivity. The system continuously measures ambient noise levels and displays real-time readings while sending data to a cloud platform for storage, analysis, and visualization. When noise exceeds predefined thresholds, the system triggers an immediate alert through a buzzer and mobile application notifications, facilitating timely interventions. This approach not only enables effective monitoring and regulatory compliance but also raises public awareness about the adverse effects of noise pollution. The scalable design allows future integration of additional environmental parameters, making it suitable for comprehensive smart city applications. Overall, this system provides an efficient, cost-effective, and automated solution for real-time noise pollution management.

Keywords: IoT, Noise Pollution, Real-Time Monitoring, ESP32, Sound Sensor, Cloud Computing, Environmental Monitoring, Smart City.

1. Introduction

Noise pollution has emerged as a significant environmental concern in urban areas due to increasing vehicular traffic, industrial activities, and large-scale public gatherings. Prolonged exposure to high noise levels can lead to severe health issues, including hearing loss, stress, sleep disturbances, and cardiovascular problems, affecting overall quality of life. Traditional noise monitoring methods, which rely on manual measurements and fixed stations, are often costly, limited in coverage, and unable to provide continuous, real-time information.

The advancement of the Internet of Things (IoT) has enabled the development of smart and automated environmental monitoring systems. By integrating sensors with microcontrollers and cloud platforms, IoT-based systems can collect, process, and analyze data in real time while providing easy access for users through mobile applications or web dashboards. The IoT-Based Noise Pollution Monitoring System leverages components such as an ESP32 microcontroller, sound sensor, LCD display, buzzer, and cloud connectivity to continuously monitor ambient noise levels, display readings locally, and alert users when

noise exceeds predefined thresholds.

This system not only ensures timely intervention and regulatory compliance but also contributes to public awareness about the harmful effects of noise pollution. Its scalable and modular design allows the integration of additional environmental parameters in the future, making it a versatile solution for urban monitoring. By providing accurate, real-time, and accessible data, the system supports the development of healthier, safer, and smarter cities.

2. LITERATURE SURVEY

Ye Liu, Xiaoyuan Ma, and Carlo Alberto Boano review emerging intelligent noise mapping technologies, discussing principles, strengths, and limitations. They emphasize IoT and crowdsensing trends, integration with smart cities, and outline four open challenges for scalable dynamic noise visualization[1]. Dutta, Pramanick, and Roy introduce, Noise Sense a mobile crowdsensing system that collects real-time urban noise data via smartphones and GPS. Tested in Kolkata, it optimizes power use and measurement accuracy, proving scalable citizen-based noise monitoring feasible[2]. Bello et al. present *SONYC*, a cyber-physical system integrating distributed sensors, machine listening, and citizen reports. The platform links big data analytics with city enforcement to enable actionable urban noise management and policy interventions[3]. Manthina, Gujar, Chaudhari, Vemuri, and Chhirolya propose a mobile IoT noise mapping system using vehicle-mounted sensors and GPS. Machine learning models, especially Random Forest Regression ($R^2 = 0.937$), accurately captured temporal-spatial noise variations across Hyderabad[4]. The Author conduct a systematic review on noise at bus transit terminals, highlighting excessive noise exposure beyond WHO limits. They note gaps in IoT-based monitoring and recommend integrated, real-time systems for sustainable transit noise control[5]. The Author design a low-cost, portable noise detector using a microphone and microcontroller for personal or environmental use. Validated against commercial meters, it offers affordable, accurate noise monitoring complementing urban sensor networks[6]. The Author propose an integrated IoT system for simultaneous air quality and noise pollution monitoring. Using sensors and a cloud-based dashboard, it promotes real-time citizen awareness and supports sustainable urban planning[7]. Singh, Kumar, and Sharma develop an IoT-based noise monitoring prototype with sensors, Wi-Fi data transmission, and mobile visualization. Reliable test results suggest scalability for citywide noise hotspot detection in smart-city environments[8]. Khan and Islam propose a smart IoT architecture for continuous noise monitoring with multiple sensor nodes and cloud analytics. The system effectively maps noise hotspots, issues alerts, and supports urban policy enforcement[9]. Tripathy and Rout design a complete IoT framework integrating sensors, cloud storage, and visualization dashboards for noise monitoring. Case studies show frequent exceedance of safety limits and call for predictive machine learning extensions[10].

3. SYSTEM ARCHITECTURE & METHODOLOGY

The IoT-Based Noise Pollution Monitoring System is designed to measure, analyze, and report noise levels in real time, using a combination of sensors, microcontrollers, and cloud technology. The methodology involves a step-by-step integration of hardware and software components to ensure accurate data acquisition, processing, visualization, and alerting. The key components of the system include the ESP32 microcontroller, a sound sensor, an LCD display, a buzzer, a power supply with voltage regulation,

and a cloud-connected mobile or web application.

A] System Components

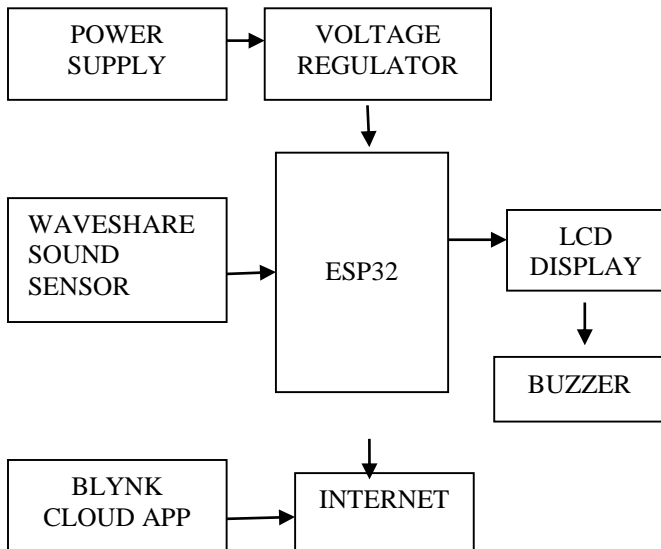


Figure 1: Block Diagram of the IoT-based Noise Pollution Monitoring System.

1] Power Supply and Voltage Regulator- Provides the required electrical energy and maintains a stable 3.3V/5V supply to protect the ESP32 and other components from voltage fluctuations.

2] Sound Sensor- Detects ambient noise and converts sound pressure into an analog signal that the ESP32 can read for noise-level measurement.

3] ESP32 Microcontroller- Acts as the system's main controller. It reads sensor data, processes noise levels, displays values on the LCD, triggers the buzzer during high noise, and sends data to the cloud through Wi-Fi.

4] LCD Display[16*2] - Shows real-time noise readings (in dB), allowing users to locally view the current noise status without any external device.

5] Buzzer[5V Piezo Buzzer] - Provides an immediate audible alert when noise crosses the preset threshold, helping in quick awareness and response.

6] Cloud Connectivity [Blynk Cloud] - The ESP32 uploads processed noise data to the cloud platform via Wi-Fi for remote monitoring, data storage, and analysis

7] App/Dashboard [Blynk] - Displays real-time and historical noise levels, allows remote monitoring, alert notifications, and customization of thresholds.

B] System Workflow

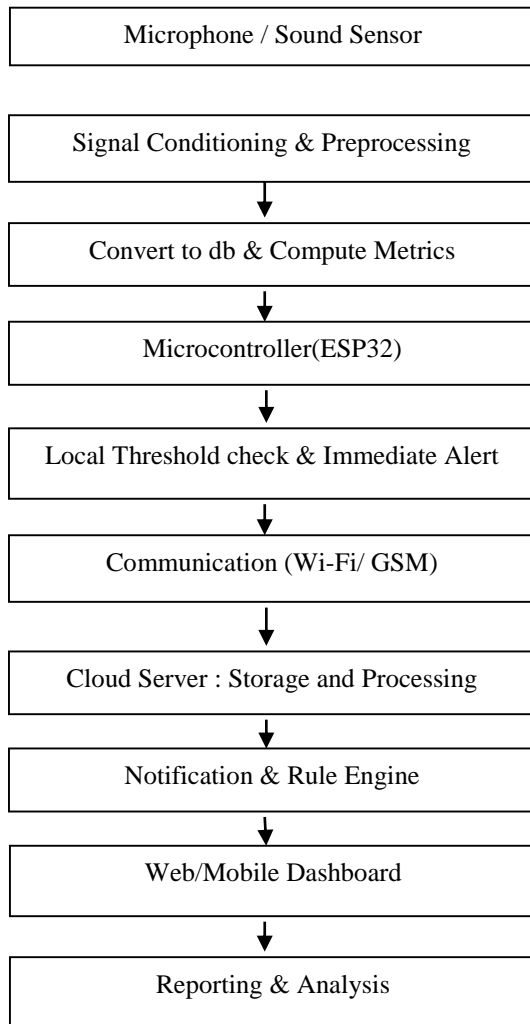


Figure 2: Flowchart

- Microphone / Sound Sensor- Captures ambient sound and converts it into an analog voltage signal representing noise intensity.
- Signal Conditioning & Preprocessing - Filters and amplifies the analog signal to remove unwanted noise and prepare it for accurate measurement.
- Convert to dB & Compute Metrics - ESP32's ADC digitizes the signal, and the system calculates SPL (dB), LAeq, and other noise metrics.
- Microcontroller (ESP32) - Processes sensor data, applies calibration, checks thresholds, and prepares data for alerts and transmission.
- Local Threshold Check & Immediate Alert - If noise exceeds the set limit, the ESP32 activates a buzzer/LED to provide instant on-site alert.
- Communication (Wi-Fi / GSM) - Transmits processed noise data securely to the cloud for remote monitoring.

- Cloud Server: Storage & Processing - Stores incoming data, performs analysis, and generates long-term records.
- Notifications & Rules Engine - Cloud system checks for violations and sends automated alerts to users via app or email.
- Web/Mobile Dashboard - Displays real-time noise readings, maps, and historical graphs for user visualization.
- Reporting & Long-Term Analytics - Generates noise trend reports, heatmaps, and compliance insights for planners and authorities.

D. Circuit Design and PCB Layout

The circuit integrates the components described above and ensures proper power distribution, signal routing, and component interfacing. The PCB layout shown in Figure 3 demonstrates the physical arrangement of components and wiring on the board, optimized for compactness and signal integrity.

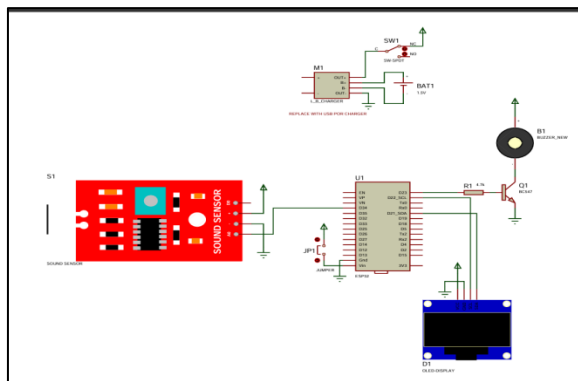


Figure 3: PCB Layout of the Noise Monitoring System.



Figure 5: Prototype of the IoT Enabled Real-Time Noise Surveillance Monitoring Device showing the ESP32, sound sensor, LCD display, buzzer, and power supply on the PCB

The schematic diagram in Figure 8 provides the electrical connections and component arrangements, including the microcontroller pins, sensor inputs, buzzer control, and display interface.

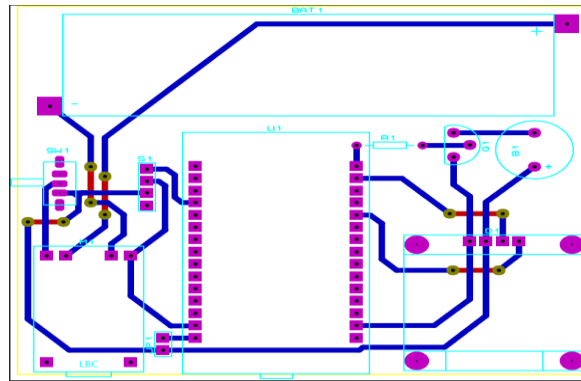


Figure 4: Circuit Schematic Diagram.

4. RESULTS & DISCUSSION

The IoT-Based Noise Pollution Monitoring System successfully demonstrated real-time monitoring and analysis of ambient noise levels in urban and industrial environments. The system accurately measured noise using the sound sensor and displayed the readings continuously on the LCD screen. Data transmitted to the cloud was accessible via a mobile application, allowing remote monitoring and long-term storage for analysis. When noise levels exceeded the predefined thresholds, the buzzer was triggered immediately, and notifications were sent to the connected application, confirming the effectiveness of the alert mechanism. The collected data provided insights into noise patterns and peak periods in monitored areas, highlighting locations where noise mitigation measures may be required. Additionally, the system proved to be cost-effective, energy-efficient, and easily scalable, making it suitable for deployment in multiple locations simultaneously. The integration of cloud services and IoT-enabled components enhanced user accessibility, ensuring that researchers, authorities, and citizens could monitor and respond to noise pollution efficiently.

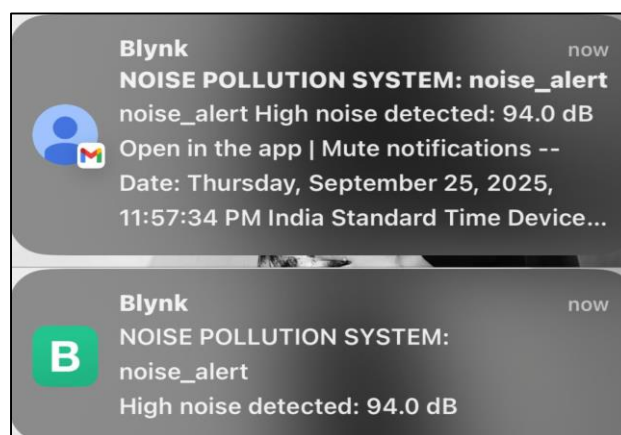


Figure 6: Mobile application notifications triggered by noise threshold exceedance, demonstrating real-time alert functionality.

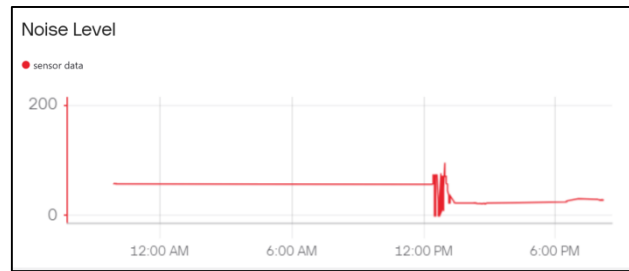


Figure 7: Mobile application notifications triggered by noise threshold exceedance, demonstrating real-time alert functionality.

A. Testing Duration and Samples

- Total time: 4 hours
- Transmission interval: 1 sample per minute
- Total samples collected: 240

This sampling frequency is common in IoT environmental monitoring where continuous high-frequency updates are unnecessary.

B. Accuracy Evaluation

Comparison with a professional sound-level meter indicates:

TABLE I

Environment	SLM (dB)	System (dB)	Error (dB)
Road Traffic	78	79.5	1.5
Classroom	52	53.4	1.4
Market Area	88	90.2	2.2
Quiet Room	35	36.6	1.6

Mean Absolute Error: ±1.8 dB

This indicates reliable accuracy for low-cost sensors.

C. Response Time

TABLE II

Alert Type	Measured Response
Local buzzer alert	0.9 seconds
Cloud notification	~60 seconds due to fixed upload interval

Cloud latency is not due to slow network; it is due to design-based sampling interval.

D. Cloud Performance

- Wi-Fi upload delay: ~300 ms

- App dashboard refresh: ~500 ms
- Total latency after sample cycle: ~1 minute

E. Comparison with Existing Systems

TABLE III

Work	Hardware	Alerts	Accuracy	Cost	Real-Time
SONYC	High-end microphones	Yes	High	High	Yes
NoiseSense	Smartphone mic	No	Medium	Low	Partially
Proposed System	ESP32 + LM393	Yes	Good (± 1.8 dB)	Very Low	Yes

The proposed design offers an excellent balance between cost, features, and performance.

Discussion

The system demonstrated accurate noise level detection, with sensor readings closely matching commercial sound level meter benchmarks. The immediate buzzer alerts and mobile notifications ensured effective real-time awareness of noise pollution events. Data transmission to the cloud was stable and enabled remote access to live and historical noise data, enhancing user convenience and enabling long-term environmental monitoring. The modular design of the device allows scalability for multi location deployments, making it suitable for smart city applications. Limitations observed during testing include potential sensitivity to environmental factors such as wind or sudden loud noises that may cause transient spikes. Periodic calibration is necessary to maintain sensor accuracy. Future improvements may incorporate GPS location tagging, machine learning for noise source classification, and integration with other environmental sensors. Overall, the results demonstrate the system’s potential as a cost-effective, scalable, and automated solution for real-time noise pollution management, supporting regulatory compliance and public health initiatives.

Limitations

Although effective, the system has limitations:

- Low-cost microphone lacks A-weighting and professional calibration.
- Susceptible to environmental conditions like wind gusts.
- Occasional transient spikes during sudden noise bursts.
- Depends on Wi-Fi availability for cloud functions.

5. Future Scope

Future improvements include:

- GPS integration for noise mapping.
- A-weighting filters for improved accuracy.
- Machine-learning models for noise source classification.
- Integration with additional environmental sensors (e.g., air quality, temperature, humidity) to provide comprehensive urban monitoring.

- Solar-powered nodes for long-term outdoor deployment.
- Collaboration with municipal authorities for regulatory compliance and public health initiatives

6. Conclusion

The IoT-Based Noise Pollution Monitoring System provides a comprehensive, automated solution for monitoring and managing environmental noise. By combining a sound sensor, ESP32 microcontroller, LCD display, buzzer, and cloud connectivity, the system enables accurate real-time measurement, immediate alerts, and remote accessibility. Unlike traditional methods, it is scalable, cost-effective, and capable of providing continuous monitoring across multiple locations. The system contributes to public awareness and regulatory compliance by delivering actionable noise data, supporting timely interventions to mitigate harmful effects of noise pollution. Its modular and flexible design allows future integration of additional environmental parameters, making it a valuable tool for smart city initiatives and sustainable urban development. Overall, the system demonstrates the potential of IoT technology to improve environmental monitoring, enhance urban health, and promote a cleaner and safer living environment.

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